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The effect of integrated science, engineering, technology, and mathematics lessons on interest and engagement of secondary students

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THE EFFECT OF INTEGRATED SCIENCE, ENGINEERING, TECHNOLOGY, AND MATHEMATICS LESSONS ON INTEREST AND ENGAGEMENT OF SECONDARY STUDENTS

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ABSTRACT

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This study set out to answer the research question: Does teaching a single lesson, utilizing the interconnected principles of STEM in STEM courses, increase overall student interest and engagement in STEM classes in secondary schools? The literature review established a need for student interest in STEM to help fill future STEM careers. Integrated STEM lessons were a viable option for increasing interest, but existing research on the matter was limited.

Integrated STEM lessons were applied at a test site school using a multiple baseline framework and evaluated responses with a variation of the Intrinsic Motivation Inventory (IMI). According to the results, two of the classes, *Natural Resources*, and *Introduction to Agriculture, Foods, and Natural Resources*, showed improved interest/motivation when exposed to an integrated STEM lesson. Two other classes, *General Science*, and *Introduction to Engineering Design*, did not show improvement, but maintained high scores on the IMI throughout the study and may have represented a ceiling effect.

At the end of data collection and analysis, it was concluded that integrated STEM lessons show potential for increasing student interest/motivation in STEM in certain contexts, depending on what was happening in each classroom.

CHAPTER 1. INTRODUCTION

1.1 Introduction

The purpose of this introductory chapter is to provide a synopsis of this thesis on the potential effects of integrated science, technology, engineering, and mathematics (STEM) lessons on student interest and engagement as compared to lessons focusing on siloed individual subjects. Throughout this chapter, importance of this quasi-experimental study will be established, as well as an overview of the thesis.

1.2 Statement of the Problem

The need for STEM education (classes focusing on science, technology, engineering, and mathematics) has greatly increased during this generation (Kuenzi, 2008; Denney, 2011). According to the US Department of Education, the United States was once known for science, engineering, and innovation, but has fallen behind when compared to other nations. Today, the number of scientists and engineers is on the decline as well as research and development investments (Denney, 2011; Munce & Fraser, 2013). Making matters worse, as few as 16% of high school graduates pursue degrees in STEM careers (United States Department of Education, 2014). President Barack Obama was quoted as saying, "…leadership tomorrow depends on how we educate our students today- especially in science, technology, engineering, and math" (Obama, 2010).

Currently, the need for STEM careers is growing at a rate three times faster than non-STEM careers and should continue to grow (United States Department of Commerce, 2011). By 2018, the number of STEM employees in the United States is projected to increase from 7.4 million to 8.65 million (Munce. & Fraser, 2013). This is largely due to the rapidly evolving high tech society, creating jobs in emerging technologies.

Research has identified several factors related to the pursuit of STEM careers; it was found that personal interest, parents, earning potential, and teachers (in that order) have the greatest influence on career decisions (Hall, Dickerson, Batts, Kauffmann, & Bosse, 2011; Beggs, Bantham, & Taylor, 2008). Additionally, students have a limited knowledge of what a STEM occupation includes (Hall et al., 2011). This study will address a few of the factors that are hindering STEM interest and measure the effects of a treatment designed to increase student interest and engagement in STEM classes.

The United States government has proposed a few ways to increase STEM interest, from better funding of STEM education to preparing more STEM educators. However, the National Academy of Engineering stated that:

> Historically, most efforts to improve STEM education at the pre-college level have focused on the individual subjects—particularly science and mathematics—rather than on how or whether they can or should be connected in ways that might improve student thinking, learning,

> engagement, motivation, or persistence. (Honey, Pearson, & Schweingruber, 2014, p. 135)

This notion of connecting STEM subjects is called STEM integration. STEM integration can be defined as a form of education in which students “work in the context of complex phenomena or situation on tasks that require students to use knowledge and skills from multiple [STEM] disciplines (Honey et al., 2014, p. 52).” Through STEM integration, educators will be able to better connect all of the aspects of STEM together in a way students can better understand (Honey et al., 2014). Students actually learn better when they are able to make more mental connections (Honey et al., 2014). According to the National Academy of Engineers, by supporting integrated STEM initiatives, students become better at addressing the following competencies:

- Recognizing and applying concepts that have different meanings or applications across disciplinary contexts (i.e., transfer).
- Engaging in a STEM practice, such as engineering design, that uses knowledge from a different discipline, such as mathematics.
- Combining practices from two or more STEM disciplines (e.g., scientific experimentation and engineering design) to solve a problem or complete a project.
- Recognizing when a concept or practice is presented in an integrated way.
- Drawing on disciplinary knowledge to support integrated learning experiences and knowing when to do so. (Honey et al., 2014, p. 37)

Proponents of integrated STEM education suggest that the interconnected principles and real world application can "enhance motivation for learning and improve student interest, achievement, and persistence" (Honey et al., 2014, pg. 1). By utilizing STEM integration, students can see a large and interconnected view of educational concepts, increasing their understanding and interest in the STEM fields.

Currently, research in all of the areas is quite limited. According to the National Academy of Engineering (Honey et al., 2014), much of the existing research is very unclear. Studies are poorly described, lack detailed methodology, and/or do not include control groups with the studies. It can also be very difficult to apply integrated STEM in public schools without some major rewrite to the curriculum (Hurley, 2001). Special STEM magnet and charter schools do exist, but even then, finding an effective way to measure improvement can be difficult (Hurley, 2001).

1.3 Research Question

Does teaching a single lesson, utilizing the interconnected principles of STEM (Science, Technology, Engineering, and Mathematics) in STEM courses, increase student interest and engagement in STEM classes in secondary schools?

1.4 Significance of the Problem

The world is continually faced with more and more complex problems and a rapid increase in evolving technologies. In fact, careers in STEM fields are growing at a rate three times faster than non-STEM careers (Psaila-Dombrowski, 2013; United States Department of Commerce, 2011). However, not enough college students are graduating with STEM degrees prepared for the high tech world, leaving promising STEM positions unfilled (Munce & Fraser, 2013). Unfortunately, there is currently a career crisis at hand, leaving 44% of recent college graduates underemployed, meaning that they work jobs that are below their educational level (Weissmann, 2014). If more students sought careers within the fields of STEM, that 44% could be reduced due to projected growth in the STEM fields (Munce & Fraser, 2013).

STEM careers have an effect on college graduate wellbeing, as well as on society, the economy, and even national security (Denney, 2011). This is problematic considering the decline of engineers, scientists, and research & development (Denney, 2011). Over the years, American STEM employees have created incredible technologies from the microwave to advancing nanotechnology, but a decline in the STEM fields could allow competing countries to surpass the United States in technical advancement (Judis, 2013). If such innovation and future growth are stifled, then the United States would “have an economy dependent on tourism, the tottering superstructure of big finance, and the export of raw materials and farm products” (Judis, 2013, p. 6). Additionally, just like the Sputnik incident in 1957, national security would be threatened by more advanced countries (National Center on Education and the Economy, 2008).

For these reasons, it is necessary that STEM career fields grow and remain strong in order to maintain this country and "provide its citizens with richer, longer, more imaginative lives" (Judis, 2013, p. 6).

1.5 Scope

Within the context of the problem of this research, there is a limit to the scope in which that can be examined. For this problem, the research will target secondary school students in the age range of seventh grade to seniors. Improving interest and engagement within STEM can enlighten students of possible engineering/technology electives and demonstrate how science and math apply to real life, thus preparing students for STEM majors in college and their career. A secondary school test site was selected due to the school partnering with Purdue University to help find ways to integrate STEM. The test site school also had the goal of becoming a STEM certified school in Indiana. Certification to become a STEM school in Indiana is a recent state wide initiative, implemented in 2014, that consists of four various levels of implementation: High School STEM Full Implementation, High School STEM Partial Immersion, High School STEM Minimal Immersion, and High School STEM Supplemental (Indiana Department of Education, 2014a). The purpose of these certifications is to prepare high school students for STEM majors and careers, share resources amongst a network of Indiana STEM schools, create community partnerships with STEM businesses and industry, and to publically endorse schools that are addressing the challenge of preparing students for the 21st century (Indiana Department of Education, 2014b).

The school principal and a team of STEM teachers from the test site school approached Purdue University to invite researchers to investigate potential outcomes of their effort. Answering their request, the researcher then sought a method to evaluate student interest and engagement when presented with an integrated STEM lesson. Students were evaluated throughout various courses related to STEM. Data collection and analysis took place during the 2014-2015 academic year.

1.6 Assumptions

During this research there were certain assumptions:

- During baseline measures, classes followed standard teaching methods, meaning teachers taught their normally planned lessons for their individual subjects as if the research was not taking place.
- The STEM integrated lessons aligned with current teaching and academic standards.
- Students responded normally and honestly when surveyed.
- Students accurately reflected on the integrated STEM learning experience.
- Cooperating teachers were certified teachers and approved of the integrated STEM lessons taught.

- Before treatment and after the treatment, students were not experiencing STEM integrated lessons.

1.7 Delimitations

During this research there were certain delimitations:

- Students not involved in STEM classes were not included.
- Aspects of motivation that were not relevant to interest and engagement were not measured.

1.8 Limitations

During this research there were certain limitations:

- The study took place at a rural Midwestern secondary school.
- Seven teachers were interested in STEM integration, but not all of them participated in the research study.
- Research took place between 2014- 2015.
- Each integrated STEM lesson was different for each participating STEM classroom.
- Only one treatment lesson was implemented per classroom.

1.9 Definitions

Integration: “Working in the context of complex phenomena or situations on tasks that require students to use knowledge and skills from multiple disciplines.” (Honey et al., 2014, p. 52)

STEM Integration: “Any program in which there is an explicit assimilation of concepts from more than one discipline. Integrated STEM education programs apply equal attention to the standards and objectives of two or more of the STEM fields – Science, Technology, Engineering and Math.” (Laboy-Rush, 2007, p.3). Agriculture was included in the STEM definition for this study because it aligned with Purdue and the test school’s initiatives.

STEM Career Fields: “Demand for skilled workers in science, technology, engineering, and math (STEM)”. (Feller & Traurig, 2010, p. 1)

1.10 Chapter One Summary

In summary, this introductory chapter has explained the problem statement that is being addressed, its significance, and some details that will be included in this study. The following chapters are used to support the need for this research with an analysis of available literature and existing studies, as well provide the research methodology that was followed in order to attain data and pursue future knowledge.

CHAPTER 2. REVIEW OF LITERATURE

The purpose of the literature review is to utilize existing sources to inform the problem, appropriate solutions, and measurement. This review will evaluate several interconnected points that will be used to support the need of integrated science, technology, engineering, and math in the education system. The review will investigate the influence of STEM workers on the economy, the lack of current need for STEM workers, what factors have led to the decrease in workers, how integrated STEM could better educate the future workforce, and how it could be implemented.

2.1 Impact of STEM Workforce

A strong workforce in the fields of science, technology, engineering, and math (STEM) have helped guide the United States into the world leadership position that it currently holds (U.S. Department of Education, 2014). Today, society is rapidly evolving in technology and other STEM fields. In fact, workers in the fields of STEM have a heavy influence in creating economic growth (Rothwell, 2013). Hira (2010) of Rochester Institute of Technology has said that it is commonly known that the STEM workforce has a large impact on the nation's standard of living, national security, and the ability to solve larger problems like global warming, terrorism, and global economic competitiveness. The influence of STEM careers on society is quite clear; President Obama has supported this by acknowledging that students should be well educated in STEM to create better leaders in the future (Obama, 2010).

However, as the United States has become more technologically evolved, the rest of the world has as well. Unfortunately, after being a leader in science, technology, knowledge generation, and innovation for so long, the United States' position of dominance is being threatened by advancing countries (Denney, 2011). This is largely due to a diminishing number of scientists and engineers as well as a decline in research and development (Denney, 2011). This is a problem for the United States if they wish to maintain global leadership. As competing countries focus on scientific excellence and technological innovation, the United States' own national security and economic growth may become less effective as they are surpassed (Denney, 2011).

This is not the first time in United States history that a national need for STEM capable employees has been documented. Cavanagh (2007) compared todays need for STEM employees to the Russian launch of the satellite, Sputnik, in 1957. The Russians were the first to launch something into space and American citizens were terrified of the unknown consequences. Because of that, a large amount of government money was spent on improving STEM classes, with a strong emphasis on science and math, in order for the United States to remain technologically competitive in the future (Cavanagh, 2007). In contrast, today there is not a powerful motivator like Sputnik, making it harder for the public to understand the need for STEM education (Cavanagh, 2007).

Why though, does the government believe that a STEM workforce is so important? The United States has been able to make amazing technological leaps while utilizing federal government funding (Judis, 2013). If it were not for such funding, inventions like microwave ovens, lasers, or even the internet may not exist as society knows it. In fact, the federal government is one of the main supporters for current developing technologies like the Human Genome Project (could radically benefit medicine), and nanotechnology (could radically benefit manufacturing (Judis, 2013). These American made technologies and the inventive STEM workers that created them have helped the United States maintain world leadership. John Judis (2013) has added a few points on the matter, saying that America without innovation, leaves an economy that only relies on tourism and the export of natural resources and farm products. Without innovation the country becomes weaker, unable to compete in the global economy and unable to provide citizens with "richer, longer, more imaginative lives." (p.6)

Education is key factor in preparing the future STEM workforce. The Committee on Standards for K-12 Engineering Education (2010) has said that "STEM education at the K-12 level is important in part because it can develop student interest and aptitude in subjects directly relevant to the nation's capacity for research and innovation." (p.5) At the very least, STEM education leads to better scientific and technological literacy, a beneficial trait for anyone (Committee on Standards for K-12 Engineering Education, 2010).

For these reasons, Congress and President Bush created the America COMPETES Act in 2007 (COMPETES standing for Creating Opportunities to Meaningfully Promote Excellence in Technology, Education, and Science) (Hira, 2010). The purpose of this act was to invest into the future STEM workforce, the main goals being, “to invest in innovation through research and development, to improve competitiveness of the United States” (House & Senate, 2014, p. 22) and “to focus on science, technology, engineering and mathematics (STEM) research and education” (DeWitt, 2011, p. 12). The COMPETES Act was designed to, as Senator Lamar Alexander (2007) put it, “ensure that the United States retains its brainpower advantage so our good jobs do not go overseas to places like India and China” (Office of Senator Lamar Alexander, 2007).

2.2 Interest in STEM Careers

In 2010, 5.5% of the national workforce was made up of STEM employees (7.4 million people), but the demand for STEM careers is now growing at a fast rate (United States Department of Commerce, 2011). The actual definition of a STEM career varies in the literature. However, for the purpose of this study, it is defined by economists of the U.S. Department of Commerce, Langdon, McKittrick, Beede, Khan, and Doms (2011), who described the 5.5% of STEM employees by placing STEM careers into four overarching categories:

1. Computer and math fields- 46% of all STEM employment.

2. Engineering and surveying occupations- 33% of all STEM employment.
3. Physical and life sciences- 13% of all STEM employment.
4. STEM management- 9% of all STEM employment.

By 2018, the number of US STEM employees is projected to increase from 7.4 million to 8.65 million (Munce & Fraser, 2013). This is largely due to the rapidly evolving high tech society, creating jobs in areas such as the “cloud” market (uploading data to the internet in order to access it anywhere), or in the application market for smartphones (Munce & Fraser, 2013).

The problem in this study however, does not come from fewer STEM employees, but from a smaller number of high school graduates interested in STEM careers. According to the United States Department of Education (2014), “only 16% of American high school seniors are proficient in mathematics and interested in a STEM career.” Further, Munce and Fraser (2013, p. 4), report similar data, saying, “Nearly 28% of high school freshmen declare interest in a STEM-related field - around 1,000,000 students each year. Of these students, over 57% will lose interest in STEM by the time they graduate from high school” (making 15.96%). That means that approximately 430,000 high school students are entering college to prepare for STEM careers, assuming that all 430,000 STEM interested high school students actually go on to college. Realistically, some students will make different decisions like going straight into the workforce or joining the military for example. However, once in college, according to Zianglei Chen (2013), of the U.S. Department of Education, many students entering STEM majors will have either changed into a non-STEM major or left college without graduation within a few years. He claimed that, “a total of 48% of bachelor’s degree students and 69% of associate’s degree students who entered STEM fields between 2003 and 2009 had left these fields by spring 2009” (Chen, 2013, p. iv). Using the estimated attrition rate of STEM bachelor’s degrees alone, the number of STEM graduates drops to approximately 206,400, nearly one million short of what is necessary for the projected STEM career growth. Other researchers refer to this notion as the “STEM pipeline,” a term used to visualize high school freshman diverting into other fields as they progress through school (Cannady, Greenwald, & Harris, 2014).

2.3 Influencing Factors

Why then, are so few graduating high school students uninterested in STEM careers? What factors cause their STEM apathy? Researchers believe that there are four main influences on student career decisions: personal interest, parents, earning potential, and teachers. This was found in Beggs, Bantham, and Taylor’s (2008) study when 852 college students of various majors were surveyed. Hall and her colleagues (2011) supported those results after surveying 118 high school students at the conclusion of a three week course called “Information Technology Academy for Students” in 2008. During the survey, it was also found that the students had very limited knowledge of STEM occupations (Hall, Dickerson, Batts, Kauffmann, & Bosse, 2011; Lichtenberger & George-Jackson, 2013). The following subsections will address these influencing factors, ordered from least to most influential: lack of STEM knowledge and understanding, parental and teacher influences, and motivational issues such as interest and self-concept (Hall et al., 2011). Earning potential is being excluded because according to the U.S. Bureau of Labor Statistics (2005), the average STEM worker makes more money than the national average. This leads to the conclusion that earning potential does not have a negative influence on STEM career choice.

2.3.1 Lack of STEM Knowledge and Understanding

The Committee on K-12 Engineering Education, Katehi, Pearson, and Feder (2009) discussed how engineering classes can be utilized to improve understanding of math and science concepts, as well as increase technological literacy; two goals of STEM integration. However, they also stated that there are various engineering misconceptions and misunderstandings that must be remedied (Katehi et al., 2009). Engineering misconceptions can start at a very young age. Many children may think of an engineer as a person who drives a train, fixes cars, is a nerd, or can only be a man (Knight & Cunningham, 2004). Knight and Cunningham (2004) claimed that secondary students generally associated engineering with building and fixing things, opposed to designing and creating. Spreading awareness even at the middle school level is crucial when preparing future engineers (Knight & Cunningham, 2004). Although children may logically drop these misconceptions due to gradual knowledge exposure or maturity, these are just some examples of negative stereotypes that may make it "increasingly difficult to attract and retain a technically proficient workforce" (Katehi et al., 2009, p. 55).

Studies have found that both students and K-12 teachers are not completely aware of what engineering entails (Katehi et al., 2009). Additionally, many adults do not even believe that engineering has much of a societal impact (Katehi et al., 2009). Generally, Americans may correlate engineering to science and math, however, they rarely correlate engineering to "creativity, rewarding work, or a positive effect on the world" (Katehi et al., 2009, p. 56). In order to help alleviate these misconceptions, it was recommended that children should be exposed to engineering/technology education and an earlier level, and that all students need to participate in engineering related activities (Katehi et al., 2009).

Hossain and Robinson (2012), provided a list of STEM misunderstandings that are hindering student interest in STEM fields:

1. STEM education is just another "fad" in education and will soon go away.
2. Colleges will not accept credits for high school courses called STEM.
3. Technology means [having] the ability of basic computing and Internet browsing.
4. STEM education consists only of the two bookends – science and mathematics.
5. STEM education addresses only workforce issues.
6. Technology education and engineering are disparate and troublesome.
7. Mathematics education is not part of science education.

8. Engineers and technology education teachers cannot teach science or mathematics.
9. STEM education includes a lot of laboratory work or the scientific method.
10. All STEM educated students will be forced to choose technical fields because they do not have a liberal arts foundation. (p. 3370)

Carter (2006) found similar misconceptions in a study in the field of computer science, a predominate STEM career, especially when considering the growing job market as (Munce & Fraser, 2013). Carter's (2006) study focused directly on computer science, however, computer science does not directly represent all STEM majors as a whole; it only serves as an example. The example of computer science was chosen because it easily combines aspects from engineering, science, mathematics, and computer technology (Denning, 2005), and because computer and math fields make up 46% of STEM careers (Langdon et al., 2011). Carter (2006) was perplexed by the declining number of computer science majors; a major that had dropped 60% in student population from 2002 to 2006. The general hypotheses to why this was revolved around misconceptions; from believing the job entailed a boring desk job, staring at a computer, to having "no information or incorrect information about what the study of computing involves and what sorts of careers are available to computing professionals" (Carter, 2006, p. 27). Carter (2006), then surveyed 836 students across nine different high schools in California and Arizona. Of those students, 363 where male, 423 were female, and 50 did not specify gender. All students were skilled in math "because research has shown a strong correlation between success in Computer Science and success in Math, Calculus and Pre-Calculus" (Carter, 2006, p. 27). The purpose of the survey was to answer four questions:

1. What kind of experience and information do High School students, on the verge of making a decision about a college major, have about the field of Computer Science?

2. What do High School students think Computer Science is?

3. What perceptions regarding the computing field do students have that would influence them for or against choosing the major?

4. Are these answers significantly different for males and females? (Carter, 2006, p. 28)

In the results, Carter (2006) found evidence supporting the original hypothesis. First, roughly half of the surveyed students imagined a computer science career to involve boring programming and staring at a computer screen all day, when in reality, the career incorporates plenty of social interaction and innovation. Second, the majority of the students could not accurately describe what a computer scientist even does. Carter (2006) linked this to the fact that only 8% of participants had ever taken a computer science class before, thus supporting the need for training more teachers. Third, it was found that female students might show more interest if they could see more application of computer science into other careers. Lastly, Carter (2006) found that student motivation towards computer science was not hindered by any financial reasons.

These studies clearly show that there are struggles in grasping exactly what STEM means or what it entails. The following sections on parental/teacher influences and motivation help address why those struggles exist.

2.3.2 Parental and Teacher Influences

The president and director of the Boston Museum of Science, Ioannis Miaoulis (2010) said in his “STEM Speech” that, “72% of U.S. engineers have had a relative that is an engineer.” There is no formal system in place that effectively informs K-12 students of the engineering field. Most information would have to come from an outside source such as a parent (Miaoulis, 2010). Miaoulis (2010) very specifically targets engineering and technology because of the direct impact of modern technology on modern day lives as well as the excellent STEM integrating experiences that come from engineering. However, so much of K-12 education focuses on just about everything except for technology (Miaoulis, 2010). Miaoulis (2010) then discussed that when the basic format for education was created over 100 years ago, technology and engineering were left out of the curriculum because the technology of that time mostly consisted of farm equipment, something that was taught at home. As technology advanced into a more industrial age, it became dangerous for children to learn alongside their parents in factories, so the children went to school instead (Hanford, 2014). Schools then experienced an influx of farm raised kids and immigrants, opposed to the middle to upper class students that they were used to. This lead to the creation of vocational schooling, largely separating the lower class students from the rest (Hanford, 2014). These lower class students were not exposed to the same level of education as the middle-upper classes, and they were no more likely to receive jobs than high school drop outs (Hanford, 2014). Many, including John Dewey, opposed the idea, angry that students were being labeled and tracked. This eventually led to the form of education that exists today, all students attending school, regardless of their origins (Hanford, 2014). Today however, technology has become so much more advanced that many parents do not know enough to teach their own kids things like car maintenance, troubleshooting, etc. (Miaoulis, 2010).

Not only are these learning opportunities hard for students to come by, but determining the amount of students that have experienced some sort of engineering education can be quite difficult, as there is no exact number. According to Katehi, Pearson, and Feder (2009), the Committee on K-12 Engineering Education, less than six million students in the United States have experienced formal engineering education since the development of K-12 engineering lessons in the early 1990's. For some comparison, there were 56 million students enrolled in either a public or private school as of 2008 (Katehi, Pearson, & Feder, 2009). Not only are there a low number of students involved, but there is only an estimate of 18,000 teachers that are qualified to teach engineering subjects (Katehi et al., 2009). To put that into better context, the committee stated that, "U.S. public and private middle and high schools employ roughly 276,000 mathematics teachers, 247,000 science teachers, and 25,000 to 35,000 technology education teachers," a drastically lower number than that of science or math (Katehi et al., 2009, p. 153). It is also very difficult to determine the effectiveness of each engineering/technology course taught. Katehi, Pearson, and Feder (2009) claimed that this is explained:

> K–12 curricular initiatives have been developed independently, often have different goals, and have been created by individuals with very different backgrounds and perspectives. In addition, the treatment of engineering concepts, engineering design, and relationships among engineering and other STEM subjects varies greatly. For these reasons, it is difficult to compare directly their strengths and weaknesses. (p. 153)

In summary, there are not enough graduating high school students who are ready to find a STEM related career. The job availability is there (Munce & Fraser, 2013; United States Department of Education, 2014), but the lack of motivational role models, such as parents or teachers, can be hindering to student interest in STEM fields (Miaoulis, 2010; Katehi et al., 2009).

2.3.3 Motivation

There are two main ways that a psychologist might describe motivation, intrinsic or extrinsic (Ryan & Deci, 2000). Intrinsic motivation is what motivates a person to accomplish a task because of the joy it brings (Ryan & Deci, 2000). For example, casually reading a book because the story is interesting is intrinsic motivation. In comparison, people are extrinsically motivated to complete tasks for the instrumental value that the task may bring, such as completing a job for the monetary reward (Ryan & Deci, 2000). Students may be intrinsically motivated in a class they genuinely enjoy, or extrinsically motivated to receive a good grade. Both motivational methods can be utilized by students as they assess their educational goals. Although there are plenty of arguments on which is more motivating, intrinsic motivation is generally considered more influential on student persistence when it comes to education (Ryan & Deci, 2000). However, in order for intrinsic motivation to be successful, three basic human needs should be met, the need to "feel connected, effective, and agentic as one is exposed to new ideas and exercises new skills" (Ryan & Deci, 2000, p. 65).

Academic interest is the biggest key factor for STEM enrollment. Students that have high amounts of interest in a subject also show a high correlation between interest and success in that subject. For example, if a student loves computers, they will most likely do better in a computer science class compared to less interest students. Interest influences "student course selection, achievement and persistence in a given field of study or career" (Beier & Rittmayer, 2008, p. 1). In fact, according to Beier and Rittmayer (2008), the most cited reason for college students leaving STEM majors is a lack of interest. In addition to those studies, after surveying 852 college students, Beggs, Bantham, and Taylor (2008) claimed that when it came to students picking a major, interest in the field was the number one motivating factor which is why this study focused on measuring motivation.

Other STEM motivational factors include student interest and self-concept (Beier & Rittmayer, 2008). Interest can be defined by student preferences of objectives, activities, or experiences (Hidi, 1990; Schiefele, Krapp, & Winteler, 1992), and "self-concept is defined as self-perceptions that fundamentally influence behavior" (Beier & Rittmayer, 2008, p. 2). Interest and self-concept are correlated with academic achievement, meaning that when students are aware of their achievement, they are motivated to continue excelling. Students are then more motivated when they credit their successes to their own hard work, as opposed to crediting success to having an easy class. Student self-concept can also be increased by proper support from someone close to the student, such as a parent or role model (Beier & Rittmayer, 2008). This fact is made more interesting when correlating the STEM workforce of 5.5% (United States Department of Commerce, 2011) to the low amount of student interest. Students may be lacking interest because of no personal associations with STEM fields. Self-concept is also developed from student perceptions when they compare themselves to fellow students and to how they do in other classes (Beier & Rittmayer, 2008). This could be problematic for engineering courses created by Project Lead the Way (PLTW), a nonprofit organization that designs engineering curriculum. PLTW is a large supporter of college education in STEM, offering high school students such benefits as scholarships or college credit (Project Lead the Way, 2014). Although helpful for students with high interest and self-concept in STEM, this could have an intimidating effect on students with low academic self-concept due to the seemingly higher difficulty.

Beier and Rittmayer (2008) conclude their literature overview with a few ways to help improve STEM interest and self-concept. Competition should be discouraged in favor of more collaborative and problem based work because competition can negatively impact the self-concept of the lower achieving students. Most importantly though, classrooms should be accommodating for students because they need to feel like they belong. This means that instructors should be well organized, welcome student questions, and consider student feedback to help shape learning activities. When students feel like they fit in or matter, interest and self-concept have a positive increase.

2.4 Integrated STEM Education as a Potential Key to Interest and Engagement

Within the past decade, there has been a new development in STEM education. The term, integrative STEM education (ISTEM) is starting to grow more popular (Sanders, 2009). Diana Laboy-Rush (2007) defined ISTEM as:

> Integrated instruction is any program in which there is an explicit assimilation of concepts from more than one discipline. Integrated STEM education programs apply equal attention to the standards and objectives of two or more of the STEM fields – Science, Technology, Engineering and Math. (p.3)

The basic principle of ISTEM is to show students the various ways that all of the STEM fields relate to each other. Many know that in the context of learning, it is beneficial to make different connections in the brain; the more a student can connect one subject to another, the easier it becomes to recall (Honey et al., 2014). However, students generally take classes that are isolated from others, specifically focusing on one subject at a time (Miaoulis, 2010). Each subject has had its own distinct class due to the many complexities that can be involved in each content area, but rarely have the subjects been combined. This educational method of isolated subject learning was originally designed in 1894 by the Harvard Committee of Ten and has not varied much since (Miaoulis, 2010; Honey et al., 2014; National Education Association, 1894). The Harvard Committee of Ten wanted to create a strong schooling experience that catered equally to all students involved (Mirel, 2006). At the time, student enrollment was set at about 359,949 students, but then sharply climbed to 4,804,255 between 1890 and 1930 (Mirel, 2006). In general, education has since followed the Committee's ideals, and because of this, few schools have attempted newer methods like ISTEM, making it difficult to find existing research on ISTEM methods.

In order to help further advance the field of ISTEM, the National Academy of Engineers published *STEM Integration in K-12 Education: Status, Prospects and an Agenda for Research* (Honey et al., 2014). The authors stated that ISTEM should be able to address five main goals:

- STEM literacy
- 21st century competencies- STEM literacy as well as 21st century competencies were chosen in order to better inform the roles of STEM in society, to become better acquainted with the STEM concepts, and to be able to critically evaluate STEM content.
- STEM workforce readiness -STEM workforce readiness is meant to increase the number of people developing STEM skills, provide necessary knowledge for the STEM related careers, and increase the pursuit of STEM degrees.
- Interest and engagement- Interest and engagement is a common goal for STEM disciplines.

- Ability to make connections among STEM disciplines- The very basis of integrated STEM is to make cross discipline connections and use those connections to improve learning. (Honey et al., 2014, p. 33)

While all goals are important, the purpose of this literature review and research is to specifically analyze how STEM interest and engagement can improve the STEM education field. However, before researching the effects of ISTEM on interest and engagement, the different types of ISTEM must be considered. There are multiple ways to implement ISTEM because it can be difficult to rework the basic education system that has been in place for so long. State departments of education are increasingly focused on STEM education, including the Indiana Department of Education (2014b) who said:

> Evolving into a STEM school environment is much more than introducing a program. For schools, this requires establishing a common local agenda to significantly improve student performance, incorporating STEM education at all levels, engaging local business and the community, and adopting new curriculum and instructional practices. A school's success depends on prioritizing STEM and putting in place effective models that best meet student needs. (p. 8)

Currently, there are a growing number of STEM charter and magnet schools that specialize in ISTEM and only accept the brightest students, but the number of those schools is unknown (Subotnik, Tai, Rickoff, & Almarode, 2010).

In order to address the effectiveness of ISTEM schools, a meta-analysis was conducted by Hurley (2001). In her analysis, she concluded that ISTEM was beneficial. Hurley (2001) set out to find the benefits of integrating science and math. Through her meta-analysis of the information, she was able to find 31 different studies comparing integrated science and math courses to nonintegrated control groups. The 31 studies used varied greatly by time, sample, and demographic. Studies found were dated from 1935 to 1997, had sample sizes ranging from 32 to 900 students, and participants aged from kindergarten to college. The length of studies were as low as two weeks and as high as 108 weeks, but rarely lasted longer than a school year. Hurley then categorized the levels of integration in order to help evaluate the student achievement levels:

- *Sequenced*: science and mathematics are planned and taught sequentially, with one preceding the other.
- *Parallel*: science and mathematics are planned and taught simultaneously through parallel concepts.
- *Partial*: science and mathematics are taught partially together and partially as separate disciplines in the same classes.
- *Enhanced*: either science or mathematics is the major discipline of instruction, with the other discipline apparent throughout the instruction.
- *Total*: science and mathematics are taught together in intended equality. (Hurley, 2001)

To summarize the results, there were a few points worth noting. Hurley (2001) found that when science and math are integrated, the benefits are not equal for each discipline. Science tended to have the best results when math was used to enhance or was fully integrated, while there were no such results in math improvement. However, an improvement in math was found when taught sequentially with science, meaning they were planned to fit together, one after the other. On the downside though, four of the six studies using this method placed math first in the sequence, making it harder to tell if integration actually made any difference. Still, through Hurley's (2001) vast meta-analysis, she recommended that ISTEM needs to be a part of all education systems.

Hurley's (2001) research also supports that there is a broad range of ways to approach ISTEM in schools. Even still, "the impact and influence of these schools is virtually unexplored by any large-scale, data-based study" (Subotnik et al., 2010, p. 12).

The main point of this literature review is to contextualize the potential benefits of ISTEM in education. ISTEM can conceivably increase student interest and engagement in the STEM fields, better preparing graduating high school students for a STEM career. Interest and engagement go hand in hand, both influencing each other. The educational philosopher, John Dewey, who lived from 1859 to 1952 (Brody, 2003), believed that interest is what influences active learning. Learning due to interest will always be more beneficial than learning due to effort (Dewey, 2012). "Interest is characterized by deep processing of information, effective learning strategies, academic and professional career choices and achievement, positive emotions, and a sense of being energized and invigorated" (Kaufman, 2014, p. 1).

2.5 Learner-Centered Teaching

Beier and Rittmayer (2008) concluded that classrooms should accommodate student learning. Efforts like organization, welcoming student questions, and considering student feedback can help shape better learning activities. Students that feel like they belong and have valued opinions will show increased interest and self-concept (Beier & Rittmayer, 2008).

Learner-centered teaching is a form of education that blends well with integrated STEM learning is. Learner-centered teaching is an educational mindset that primarily focuses on students guiding their own learning, opposed to the more traditional form of fact based lecturing. The method encourages student participation, critical thinking, meaningful experiences, real-world application, creativity, and discovery both in and out of the classroom (Knobloch, 2009).

Learner-centered teaching, or constructivism, has many differences when compared to traditional teaching, or behavioralism. Behavioralist teachers tend to be in charge; they are a knowledge authority while students simply receive that knowledge. Constructivists take a step back from authority and into more of a facilitator roll, trying to instead guide students into building their own knowledge. Behavioralists rely on the recollection of facts; they assess knowledge through right or wrong test answers. On the other hand, constructivists will assess through observations of student growth, participation, points of view, as well as some testing. Constructivists know that student knowledge is always developing throughout experiences and look for new ways to apply it. Last, behavioralists generally assign students to work alone. Constructivists tend to allow students to work together in order for them to learn from each other’s knowledge and experiences (Concept to Classroom, 2004).

Learner-centered teaching is made up of three main categories that can be utilized: active learning, inquiry learning, and contextual learning. Active learning is used to get students involved in the class while highly encouraging interest and participation. Some examples could include group discussions, peer guided learning, visual instruction, or role-playing. Inquiry learning focuses on reaching understanding through problem solving and critical thinking. Examples could include problem based activities, case studies, or project development. Last, contextual learning focuses on real world contexts. Students develop a greater understand of their knowledge by applying it to real life. This allows students to consider the needs of real people or impacts on the environment. Contextual learning works especially well with concepts like the engineering design process; allowing students to think through steps that apply to the real world (Knobloch, 2009).

Learner-centered teaching excels in creating opportunities for student engagement, inquiring, real world experience, and flexible learning. Learner-centered teaching should be used in tandem with integrated STEM learning in better increase student interest and engagement.

2.6 Chapter Two Summary

This literature review has revealed that there is an evident need for a larger STEM work force, yet schools are not producing enough potential STEM employees. There are a few factors relating to the lack of student interest, there are misconceptions regarding engineering and other STEM courses, as well as deficiencies in student motivation, interest, and self-concept. Through some studies, it is clear that integrated STEM education can be beneficial, but there are not many existing studies that address how exactly students are affected by ISTEM. According to the National Academy of Engineering, one of the goals of ISTEM is to increase student interest and engagement, which can lead to better overall academic achievement and interest in the STEM fields (Honey et al., 2014). Therefore, this means that there is great potential for conducting future research on the matter.

CHAPTER 3. METHODOLOGY

The purpose of this quasi-experimental study was to answer the research question “Does teaching a single lesson, utilizing the interconnected principles of STEM (Science, Technology, Engineering, and Mathematics) in STEM courses, increase student interest and engagement in STEM classes in secondary schools?” In order to do this, various STEM lessons were applied in differing classrooms at a secondary high school testing site. Student interest was measured using the Intrinsic Motivation Inventory, then student responses were evaluated using a multiple-baseline research design (A-A-B-A-A).

3.1 Hypotheses

This study includes the following hypotheses:

H_o: The implementation of an integrated science, technology, engineering, and mathematics lesson will not have an effect on student interest and engagement within STEM courses.

H_{A1}: The implementation of an integrated science, technology, engineering, and mathematics lesson will have an effect on student interest and engagement within STEM courses.

H_{A2}: The implementation of an integrated science, technology, engineering, and mathematics lesson will have a positive effect on student interest and engagement within STEM courses.

3.2 Framework

3.2.1 Integrated STEM Lesson Development

Prior to this research, the test site school sought to create a partnership with the Colleges of Education, Agriculture, and Technology at Purdue University in order to create integrated STEM lessons. A partnership was formed with the Purdue class titled, *Methods of Integrated STEM Education* (cross-listed as IT 472/581/EDCI490/590). The preservice teachers in that class were then tasked with developing STEM integrated lessons to be implemented at the test site school. The course, *Methods of Integrated STEM Education*, was described in the syllabus:

> This methods course will focus on operationalizing the theoretical pedagogical approaches to integrated Science, Technology, Engineering and Mathematics (STEM) education. Students will collaboratively and cooperatively investigate, plan and deliver integrated learning experiences appropriate for secondary education. Course content will blend philosophical considerations with practical application. (Mentzer, Knobloch, & Ryu, 2014)

The course was made up of four graduate and two senior undergraduate students, all of which were majoring in an educational field within a STEM discipline. Three students from engineering/technology backgrounds, two from agricultural backgrounds, and one from a science/physics background. The course was co-taught by Dr. Nathan

Mentzer, professor in Engineering/Technology Teacher Education; Dr. Neil Knobloch, professor in Youth Development and Agricultural Education; and Dr. Minjung Ryu, professor in Chemistry Education.

The Methods of Integrated STEM Education class was able to partner with the secondary school within this study and teach a lesson at the school. At the beginning of the fall 2014 semester, the Purdue pre-service teachers were tasked with creating an integrated STEM lesson that utilized learning standards from at least three STEM content areas. While creating the integrated STEM lessons, the Purdue pre-service teachers worked very closely with the course professors, guest lecturers who specialized in various STEM content areas, and STEM teachers from the test site school in order create the lesson plans delivered at the school mid-year.

3.2.2 Integrated STEM Lessons

The integrated STEM lessons were unique to each of the six Purdue preservice teachers. However, they all closely follow the goals and objectives provided by the *Methods of Integrated STEM Education* class:

At the end of this course, students should be able to:

1. Engage in instructional conversations, collaboratively share instructional resources, and develop a sense of community for integrated STEM learning and teaching.
2. Contextualize STEM learning in authentic contexts.

3. Explain and apply socially and culturally relevant pedagogy in the context of STEM learning.
4. Discuss levels and types of integrated STEM content, pedagogy, and ways of knowing.
5. Develop and disseminate integrated STEM learning experiences.
6. Implement, assess and reflect on integrated STEM learning experiences.
7. Students will be able to articulate a framework explain integrated STEM education.
8. Students can adapt existing singular discipline curriculum resources to leverage connections across disciplines to facilitate integration. (Mentzer, Knobloch, & Ryu, 2014)

3.2.3 Abstract and Objectives of Integrated STEM Lessons

The Purdue preservice teachers followed strict guidelines in order to create more effective lessons. Within the *Methods of Integrated STEM Education* class, preservice teachers first focused on their core content area, depending on which educational department they reside. The preservice teachers then audited a STEM classroom at the test site school to better see how the school functioned. Then, while focusing on learner-centered teaching, the preservice teachers built a lesson that still focused on a core STEM discipline, but also focused on another STEM discipline as support, using standards from both disciplines. During lesson construction, guest lecturers, who were experts in a given STEM field, critiqued and offered advice on how to better incorporate content from multiple STEM disciplines. Preservice teachers then created a final lesson plan that relied on active and inquiry learning, and three separate STEM disciplines, after receiving feedback from the *Methods of Integrated STEM Education* professors, their peers, and the cooperating STEM teachers from the test site school. The preservice teachers then delivered their lesson (the treatment) at the test site school at the end of the semester after two to three practice runs within the *Methods of Integrated STEM Education* class. (Mentzer, Knobloch, & Ryu, 2014)

Provided below are abstracts and objectives for each integrated STEM lesson created by the Purdue preservice teachers. This section demonstrates the quality of each lesson and enables sharing of the content with other teachers. The full lessons can be found in Appendix C. Each Purdue preservice teacher granted permission for their work to be used in this study and the following abstracts and objectives are in their own words, not the researcher's. It is noticeable in the abstracts that there are only four lessons present even though six Purdue students were involved. Two lessons were dropped due to a poor response rate from student participants; this is further addressed in section 3.3.2 and in the Results.

<u>3.2.3.1 Integrated STEM Lesson: Extreme Makeover School Edition</u>

The following lesson was taught in the *Introduction to Agriculture, Foods, and Natural Resources* class at the test site school.

Abstract:

Extreme Makeover School Edition was a lesson planned for a Career and Technical Education Agriculture course. The lesson was facilitated in an *Introduction to Agriculture, Food, & Natural Resources* class of students ranging from 8^{th} – 12^{th} grade (with most being in 8^{th}). However, small modifications could be made to make it appropriate for several other Agriculture classes including: Plant & Soil Sciences, Natural Resource Management, Landscape Design, and Horticulture Science. The lesson utilized the engineering design process, encouraged students to focus on user centered design and constraints, while allowing students the opportunity to learn about plants and the needs of wildlife through designing a to-scale landscape design. (Scherer, 2014)

Learning Objectives: At the end of this lesson, students will be able to:

1. Apply the engineering design process.
2. Design a wildlife habitat.
3. Describe human impact on ecosystems.

Brief overview of standards:

- Introduction to Agriculture, Food, and Natural Resources Standard 2.1
- Eighth Grade Science Standards
    - 8.2.6
    - 8.2.8
    - 8.3.1
- Standards for Technological Literacy
    - 15 I

    - 15 N

- Seventh Grade Math Standard 7 GM 3

Refer to Appendix C for full lesson plan.

3.2.3.2 Integrated STEM Lesson: Reduction of Bass Population

The following lesson was taught in the *Natural Resources* class at the test site school.

Abstract:

In this case study, students are exposed to a real problem (reduction of bass population) in a local context. Their task is analyzing data collected by a group of local researchers and making inferences from data and information presented in the case regarding the possible causes of the reduction of bass population in lake (predators, human intervention during the fish spawning season, habitat characteristics). As a product, students formulate ideas to design a management plan to protect bass population in the lake as it was required by the client in the engineering process. An adequate management plan provides ecological protection but also economic and sociological benefits for enjoyment of the local community and tourists. (Espinoza Morales, 2014)

Learning Objectives: At the end of this lesson, students will be able to:

1. Identify characteristics of a healthy wildlife habitat.
2. Make inferences from data to predict results.
3. Formulate ideas to design a management plan.

Brief overview of standards:

- Natural Resources Core Standards
    - NR 7.1
    - NR 7.3
- Indiana Academic Standards for Mathematics; Ninth Grade
    - Standard 1
    - Standard DSP.1 in Algebra Two
- Standards for Technological Literacy 15N

Refer to Appendix C for full lesson plan.

3.2.3.3 Integrated STEM Lesson: DNA and Society

The following lesson was taught in the *General Science* class at the test site school.

Abstract:

The DNA and Society lesson touches on Technology, Science, and Math over three lessons. The entire lesson is built on a narrative in which the students act as investigators, hired by employees of a company. These employees are worried that the company is collecting their DNA and it is up to the investigators to look into questions the employees have.

On the first day students research the questions of why the company might want to collect DNA and how it is collected. Topics such as genetic discrimination are singled out to prompt students to think of ethical implications of technology.

On the second day students attempt to find out the amount of DNA in a person buy carrying out a strawberry DNA extraction activity and then using knowledge of proportions and ratios to make an estimate. Students are also prompted to write down their observations of the experiment.

On the third day students are asked to compare their yields of DNA and asked to think why they got different results. This leads to an introduction to scatterplots and other data analysis appropriate for the 8th grade level. After this students are asked to write a final report that summarizes their thoughts based the technological issues researched on the first day, the ease of the DNA extraction process on the second, and the amount of DNA determined from the calculations. (Johns, 2014)

Learning Objectives: At the end of this lesson, students will be able to:

1. Construct explanations, via research, describing how knowledge from DNA affects society.
2. Recognize how the ability to extract DNA affects society.
3. Extract DNA from strawberries.
4. Observe what DNA looks like to the naked eye.
5. Compare proportions to estimate the amount of DNA in other biological systems.
6. Construct scatter plots to perform data analysis on the extraction process.
7. Understand what a positive and negative correlations are.
8. Understand what a linear fit is.
9. Recognize the concept of error in measurements.

Brief overview of standards:

- Indiana Standards Three Life Sciences 8.3.4
- Indiana Process Standards for Mathematics PS.4
- Standards for Technology Standard 4

Refer to Appendix C for full lesson plan.

3.2.3.4 Integrated STEM Lesson: Friction on the Road

The following lesson was taught in the *Introduction to Engineering Design* class at the test site school.

Abstract:

Friction on the Road is a lesson designed for either an Introduction to Engineering or Transportation 1 class. This particular lesson is based on an inquiry approach to learning. The lesson starts with a set motivation through two videos which demonstrate extreme examples of friction and its impact on vehicles. Next the students participate in a brainstorming activity to prepare them for the Investigation activity. The activity is designed to allow the students to explore friction and how it might impact the system of transportation. The activity involves a Hot Wheels track, Hot Wheels, and a custom designed sled. The purpose of this lesson is to demonstrate to students that the principles and theories they learn in their science class have a real world application. Through completion of this lesson students also engage in authentic STEM practices, which prepare them for a later design challenge. By providing students with an authentic inquiry experience they are able to observe the connection that

modeling and experimentation has with engineering design and science. (Coots, 2014)

Learning Objectives: At the end of this lesson, students will be able to:

1. Explain the concept of Friction as it relates to traction in an automotive system.
2. Analyze variables within the stated system and identify which variables significantly impact the efficiency of the system.
3. Consider which variable(s) could be used in a design brief and identify which variable they will address in their design.
4. Summarize the investigation and analysis in their notebook, it should include definitions of variables, descriptions of tests, data table of results, analysis, and a reflection.

Brief overview of standards:

- Standards for Technological Literacy Standard 3
- Mathematics
  - PS.2
  - PS.3
- Integrated Chemistry-Physics RS.5

Refer to Appendix C for full lesson plan.

The following tables 3.1 and 3.2 were used in the *Methods of Integrated STEM Education* course and describe how the content was utilized in the treatment lesson provided by the Purdue preservice teachers (Mentzer, Knobloch, & Ryu, 2014)

Table 3.2.3.1
Pedagogical Principles that Enable Integration

Course	Lesson Title	Real-World Problems	Role Playing	Social & Cultural Factors	Objects	Multiple Representations
Natural Resources	Reduction of Bass Population	Lake Freeman	Like a Scientist	Environment		Tables, newspaper, write, speak
General Science	DNA and Society	DNA Inquiry	Like a Scientist	Ethics		
Introduction to Engineering Design	Friction on the Road	Motivation Video	Student Personal Experiences	Video	Hot Wheels, Sled	Videos, Hot Wheels, Sled
Introduction to Foods, Agriculture, and Natural Resources	Extreme Makeover School Edition	Landscape Design Challenge	Like Designers	History of Area Human Impacts	Grid Paper	Incorporated Video

Table 3.2.3.2

Content Integration in Six Lessons

Course	Lesson Title	Science	Technology/ Engineering	Mathematics	Agriculture
Natural Resources	Reduction of Bass Population		Design	Estimation Justify Conclusions	* Reproduction Habitat
General Science	DNA and Society	* DNA	Design & Ethics	Data Analysis	
Introduction to Engineering Design	Friction on the Road	Forces	* Design	Reasoning, variables and relationships	
Introduction to Foods, Agriculture, and Natural Resources	Extreme Makeover School Edition	Humans vs. Biosphere Reproduction	Design	Scale, geometry, length, area, proportional reasoning	* Habitat Communication Skills

Note- * represents the anchor discipline or area of study

3.3 Participants

3.3.1 Test Site School

The school chosen for sampling was a rural secondary school consisting of 333 students, grades 7-12, with 28% on free or reduced lunch (DOE Compass, 2014). This school was chosen for two main reasons: 1) the school was searching for ways to implement STEM integration in order to become a STEM certified high school in the state of Indiana, and 2) the principal approached Purdue University in order to invite in research opportunities. Grades 8-12 are included in this study, all of them under one principle.

3.3.2 Participating Students

The participating students were not chosen by the researcher, minimizing selection bias. Instead, six Purdue preservice teachers in the IT 581/EDCI490/590 course each chose a single participating STEM teacher and class period at the test site school in which to implement an integrated STEM lesson. The secondary students within each chosen class at the test site school were used in this study.

Five sample STEM classes were chosen for implementation: one science, two agricultural science, and two engineering/technology class. However, two lessons were implemented in one of the engineering/technology classes but were then dropped from this research due to insufficient survey response rates from the participating students. The agricultural science teacher was licensed in Agricultural Education and was in her first year of teaching. The science teacher was licensed in Science education and had multiple years of teaching experience. The engineering/technology teacher was licensed in Technology Education and had been teaching for three years. The demographics for each class are listed below, followed by class descriptions according to the Indiana Department of Education (2013):

- *Introduction to Agriculture, Foods, and Natural Resources*, Grades 8-12, 17 students.

  Introduction to Agriculture, Food and Natural Resources is a two semester course that is highly recommended as a prerequisite to and a foundation for all other agricultural classes. The nature of this course is to provide students with an introduction to the fundamentals of agricultural science and business. Topics to be covered include: animal science, plant and soil science, food science, horticultural science, agricultural business management, landscape management, natural resources, agriculture power, structure and technology, leadership development, supervised agricultural experience and career opportunities in the area of agriculture, food and natural resources. (2013a, p. 34)
- *Natural Resources* (College Dual Credit), Grades 10-12, 11 students.

  Natural Resources is a two semester course that provides students with a foundation in natural resources. Hands-on learning activities in addition to leadership development, supervised agricultural experience and career exploration encourage students to investigate areas of environmental concern. Students are introduced to the following areas of natural resources: soils, the water cycle, air quality, outdoor recreation, forestry, rangelands, wetlands, animal wildlife and safety. (2013a, p. 35)

- *General Science*, Grade 8, 25 students.

  Students in eighth grade understand how atomic structure determines chemical properties and how atoms and molecules interact. They explain how the water cycle and air movement are caused by differential heating of air, land, and water and how these affect weather and climate. They understand that natural and human events change the environmental conditions on the earth. They understand the predictability of characteristics being passed from parent to offspring and how a particular environment selects for traits that increase survival and reproduction by individuals bearing those traits. (2013b, p. 41)

- *Introduction to Engineering Design*, Grade 9, 15 students.

  Introduction to Engineering Design is an introductory course which develops student problem solving skills using the design process. Students document their progress of solutions as they move through the design process. Students develop solutions using elements of design and manufacturability concepts. They develop hand sketches using 2D and 3D drawing techniques. Computer Aided Design (CAD). (2013a, p. 73)

3.3.1 Institutional Review Board

Before research began, the principal of the test site school decided that this research was important enough to be mandatory for all students involved, negating the need for parental consent. The integrative STEM lessons had already been planned for implementation by the Purdue course professors and the test site school principal before this research was designed. Due to the nature of this research and simple evaluation of the lessons, Category One Research Exemption was granted by the Institutional Review Board (Refer to Appendix B for approval letter).

3.4 Research Design

It was decided that a multiple-baseline research design would be most useful for gauging effectiveness. The textbook, *Educational Research: Competencies for Analysis and Applications*, defined multiple-baseline design as such:

> Data are collected on several behaviors for one subject, one behavior for several subjects, or one behavior over a period of time, the treatment is systematically applied to each behavior (or subject setting) one at a time until all behaviors (or subjects or settings) are exposed to the treatment. (Gay, Mills, & Airasian, 2009, p. 284)

Based off of that definition, this research will measure one behavior for several subjects over a period of a time. This method was chosen because of the limitations of this study. All of the classes that are being evaluated are receiving an integrated STEM lesson, meaning that there is no control group per se. By using a multiple-baseline method, the students can be compared to their own learning experiences, both prior and after the integrated STEM lesson (A-A-B-A-A replication). Essentially, multiple-baseline design utilizes repeated measures to establish a baseline, or a predicted path if students were to continue without intervention. Once the independent variable, integrated STEM lessons, is introduced, change to the baseline may be credited to the independent variable (Wolff, 2008).

Prior to the integrated STEM lesson taught by Purdue preservice teachers, the STEM teachers of the test site school had one week to implement the survey two times, one after each of two different typical lessons. Teachers were given a one week time frame to implement the survey because timing needed to remain consistent. The survey was implemented again after the integrated STEM lesson, then again two more times the following week during two typical lessons.

It is not necessary that the research method begin at the exact same time for all participants (Morgan & Morgan, 2009). This is called nonconcurrent multiple-baseline design, meaning that collection of data does not happen simultaneously across subjects (Morgan & Morgan, 2009). In fact, when implementation of the treatment is applied at a different time for each class, it strengthens the results (Morgan & Morgan, 2009). Any change to the independent variable can then be correlated to the treatment, instead of outside threats like maturation. If all treatment happened at the same time, or concurrently, outside factors besides the treatment would need to be considered

(Morgan & Morgan, 2009). Integrated STEM lessons will be taught on separate days for each class, but will still procedurally follow the timeline of implementing two baseline surveys during the week prior and after the integrated STEM lesson. This will allow the study and data collection to remain consistent, which is necessary (Morgan & Morgan, 2009).

This research focused on interest/engagement for multiple STEM subjects. Teachers received the online survey instrument as an internet web link and asked students to answer the 3-5 minute survey after each lesson/activity. This happened two times following traditional lessons before the treatment lesson was introduced in order to establish a baseline, as a minimum of two baselines was recommended (Barlow, Nock, & Hersen, 2008). The survey was given after the treatment lesson, then two more times after the treatment to reestablish a baseline. Although not always necessary, establishing a second baseline after treatment is done to show the controlling effects of the treatment (Multiple Baseline Designs, n.d.). If the second baseline returns to the level of the first, this may show that any change to the independent variable was due to treatment. In total, the survey was implemented five times; two before, one treatment, and two after.

3.5 Assessment Instrument

The chosen instrument was based off of the Intrinsic Motivation Inventory (IMI). The IMI originated in the 1980's and has been used by in many studies dealing with motivation and self-regulation (Intrinsic Motivation Inventory, n.d.).

Although motivation, not interest, is in the title, “motivation and interest have been consistently linked in past research,” making it a viable instrument (Deci, 1992).The IMI is made up of seven subscales that attempt to measure:

1. Interest/enjoyment

   a) I enjoyed doing this activity very much.
   b) This activity was fun to do.
   c) I thought this was a boring activity. (R)
   d) This activity did not hold my attention at all. (R)
   e) I would describe this activity as very interesting.
   f) I thought this activity was quite enjoyable.
   g) While I was doing this activity, I was thinking about how much I enjoyed it.

2. Perceived competence

   a) I think I am pretty good at this activity.
   b) I think I did pretty well at this activity, compared to other students.
   c) After working at this activity for a while, I felt pretty competent.
   d) I am satisfied with my performance at this task.
   e) I was pretty skilled at this activity.
   f) This was an activity that I could not do very well. (R)

3. Effort/Importance

   a) I put a lot of effort into this.
   b) I did not try very hard to do well at this activity. (R)

c) I tried very hard on this activity.

d) It was important to me to do well at this task.

e) I did not put much energy into this. (R)

4. Value/usefulness

a) I believe this activity could be of some value to me.

b) I think that doing this activity is useful.

c) I think this is important to do.

d) I would be willing to do this again because it has some value to me.

e) I think doing this activity could help me.

f) I believe doing this activity could be beneficial to me.

g) I think this is an important activity.

5. Felt pressure and tension

a) I did not feel nervous at all while doing this. (R)

b) I felt very tense while doing this activity.

c) I was very relaxed in doing these. (R)

d) I was anxious while working on this task.

e) I felt pressured while doing these.

6. Perceived choice

a) I believe I had some choice about doing this activity.

b) I felt like it was not my own choice to do this task. (R)

c) I did not really have a choice about doing this task. (R)

d) I felt like I had to do this. (R)

e) I did this activity because I had no choice. (R)

f) I did this activity because I wanted to.

g) I did this activity because I had to. (R)

7. Relatedness (validity not yet established)

a) I felt really distant to this person. (R)

b) I really doubt that this person and I would ever be friends. (R)

c) I felt like I could really trust this person.

d) I would like a chance to interact with this person more often.

e) I would really prefer not to interact with this person in the future. (R)

f) I do not feel like I could really trust this person. (R)

g) It is likely that this person and I could become friends if we interacted a lot.

h) I feel close to this person.

These seven subscales are used to evaluate effectiveness after a single lesson (Intrinsic Motivation Inventory, n.d.). The IMI uses various statements that students can agree or disagree with using an affective scale from one to seven. The instrument explains that not all subscales are needed, and that subscales can be removed depending on the focus of the research. An entire subscale can be removed, but removing individual items at random will have negative effects on reliability and validity. The instrument (Intrinsic Motivation Inventory, n.d.) claimed that:

> Past research suggests that order effects of item presentation appear to be negligible, and the inclusion or exclusion of specific subscales appears to have no impact on the others. Thus, it is rare that all items have been used in a particular experiment. (p. 1)

Other than the Relatedness subscale, which was added at a later date, the IMI was confirmed to be valid in by McAuley, Duncan, and Tammen (1987) when they found that the overall scale was internally consistent with an alpha coefficient of .85.

For the purpose of this research, only the four scales, interest/enjoyment, perceived competence, effort, and value/usefulness will be used, making a total of 25 items. The smaller scale was chosen because the four subscales used are those best aligned with interest and engagement, and the smaller total maximized student time and attention while complying with the instrument.

3.6 Lesson Structure Overview

In order to better compare treatment results, interviews were conducted with the participating teachers at the sample school. The purpose of the interviews was to identify what was happening during the surveyed lessons, both before and after the treatment lesson. Again, all participating teachers surveyed students after two separate lessons before the treatment and two separate lessons after. The teachers were asked to briefly describe what happened in each lesson and answer a few pedagogical questions.

When asked about the general pedagogical layout of the class, the teacher was to address these points: lesson structure, STEM content, engagement, and active learning. Lesson structure was categorized into five parts: authority/lecture, demonstrator, facilitator/activity, delegator/group, or a hybrid between multiple parts, based off of *Five Types of Effective Teaching Styles of 21st-Century Classrooms* by Gill (2014). The teacher was then questioned about integrated STEM concepts. The National Academy of Engineering (Honey et al., 2014) explained that integrated STEM concepts should include content transferability, multiple representations, real world situations/applications, and standards crossing multiple STEM disciplines. Lastly, the teacher was asked if he/she witnessed student engagement throughout the lessons, based off of their own observations. Tables of their responses can be found below.

3.6.1 Introduction to Agriculture, Foods, and Natural Resources

Condition	A	A	B	A	A
Delivery Date	12/02/2014	12/03/2014	12/05/2014	12/11/2014	12/12/2014
Topic	Sheep/Goat Identification	Sheep/Goat Identification	Extreme Makeover: School Edition	E-learning Trial Day	Final Review
Objective	Students will be able to analyze differences between different types of sheep and goats using different pictures.	Students will continue analysis and discover correct answers through trial and error and teacher intervention.	Students will utilize the engineering design process and knowledge of agricultural functions to plan a new entry way into the school.	Students will demonstrate competence of the e-learning system through online activities provided by the teacher.	Students will recall previously learned concepts through the review game, Jeopardy.
Lesson Structure	Lecture, Student work day	Student work day	Lecture, demonstration, and group work	Lecture and individual work time	Group Work/Game
Use of Integrated STEM Practices	Real-World Application	Real-World Application	-Real-World Application -Engineering Design Process -User-Centered Design	None	None
Observed Engagement	Cooperating teacher reported that they were able to witness student participation and visible interest throughout the lessons				
Student Gender	3 female, 15 male				

3.6.2 Natural Resources

Condition	A	A	B	A	A
Delivery Date	12/02/2014	12/03/2014	12/05/2014	12/11/2014	12/12/2014
Topic	Extinction	Extinction	Data Analysis of Bass Reduction	Extinction Quiz/Test	E-learning Trial Day
Objective	Students will apply knowledge about extinction and its causes in order to develop ideas to preserve animals today.	Through research, students will identify three ways in which humans have caused extinction.	Students will formulate ideas and design a management plan to protect the bass population in a real-world scenario.	Students will recognize and describe how extinction applies in modern situations.	Students will demonstrate competence of the e-learning system through online activities provided by the teacher.
Lesson Structure	Student presentations	Lecture, and Student research	Lecture, Activity, and Group work	Quiz/Test	Lecture and individual work time
Use of Integrated STEM Practices	Real-World Application	Real-World Application	-Real-World Application -Statistical Analysis -Engineering Design Process	Real-World Application	None
Observed Engagement	Cooperating teacher reported that they were able to witness student participation and visible interest throughout the lessons				
Student Gender	4 female, 7 male				

3.6.3 General Science

Condition	A	A	B	A	A
Delivery Date	11/24/2014	11/25/2014	12/05/2014	12/09/2014	12/10/2014
Topic	DNA: GATTACA	DNA: Continued	DNA and Society	DNA Classification	DNA Classification and Final Review
Objective	Given a movie, students will draw connections between the movie and concepts learned in class.	Students will discuss thoughts on the movie and share their reactions about “genoism.” Students will also work together to solve a DNA based math problem.	Students will act as investigators, applying their knowledge of DNA and extraction to address real-world problems.	Students will complete activities over DNA classification.	Students will complete activities over DNA classification. Students will also prepare for the class final.
Lesson Structure	Movie	Discussion and Group work	Lecture, Demonstration, and Group work	Lecture and Group Work	Lecture and Group Work
Use of Integrated STEM Practices	Real-World Application	-Real-World Application -Mathematical Concepts	-Real-World Application -Technology Concepts -Mathematical Concepts	Real-World Application	Real-World Application
Observed Engagement	Cooperating teacher observed student engagement, participation amongst peers during classification activities, and group discussion when talking about genoism.				
Student Gender	16 female, 8 male				

3.6.4 Introduction to Engineering Design

Condition	A	A	B	A	A
Delivery Date	12/03/2014	12/04/2014	12/07/2014	12/08/2014	12/10/2014
Topic	Puzzle Cube	Puzzle Cube	Friction on the Road	Puzzle Cube	Puzzle Cube
Objective	Students will utilize their abilities in design, 3D modeling, crafting, and assembling to create a functional puzzle cube.	Students will utilize their abilities in design, 3D modeling, crafting, and assembling to create a functional puzzle cube.	Students will demonstrate how the principles and theories of friction affect transportation using real-world application.	Students will utilize their abilities in design, 3D modeling, crafting, and assembling to create a functional puzzle cube.	Students will utilize their abilities in design, 3D modeling, crafting, and assembling to create a functional puzzle cube.
Lesson Structure	Work Day	Work Day	Lecture, Demonstration, and Activity	Work Day	Work Day
Use of Integrated STEM Practices	-Engineering Concepts -Technology Concepts -Mathematical Concepts	-Engineering Concepts -Technology Concepts -Mathematical Concepts	-Real-World Application -Engineering Concepts -Technology Concepts -Mathematical Concepts	-Engineering Concepts -Technology Concepts -Mathematical Concepts	-Engineering Concepts -Technology Concepts -Mathematical Concepts
Observed Engagement	Cooperating teacher observed that students were engaged. They all participated and spent their available time on task.				
Student Gender	2 female, 14 male				

3.7 Analysis

3.7.1 Data Collection

In order to collect data, the instrument had been converted to an online survey that students could fill out when provided with a link. All students at the test site school had their own Google Chromebooks to use in class and at home, giving them easy access to the surveys. As homework, the students were able to reflect on that day's lesson before class the next day and receive credit for each completed survey. The survey gathered data on the variables: IMI measurements, student identifiers, participating teachers, and class periods. Data was compiled on an online spreadsheet, converted to Excel, and then deleted from the internet.

3.7.2 Analysis Procedures

After data had been collected from all classes, the total score for each survey implementation was added up individually, followed by finding the class average. From that point there were multiple analyses to evaluate:

- Utilizing all provided data, the average baseline scores were compared to the average treatment scores using pairwise comparison.
- Evaluating the data from each individual STEM class, in order to evaluate effectiveness in each separate class, the average baseline scores were compared to the average treatment scores using pairwise comparison.
- The survey was then reorganized into the subscales: interest/enjoyment, perceived competence, effort, and value/usefulness in order to evaluate

which subscales encountered the most variation. Comparisons were made through visual analysis of graphed averages for each class.

In order to gauge statistical significance, and alpha of .05 was used. Pairwise comparison results that were less than or equal to .05 demonstrated that any change encountered happened during implementation of the independent variable, integrated STEM lessons.

After attempting to find an effective means of statistical analysis, research results have been inconclusive. Many multiple-baseline designs rely on interpreting line graphs instead of statistics, as said by Rhoda, Murray, Andridge, Pennell, and Hades (2011, p. 2165): "…MBDs in applied behavior research have traditionally been analyzed by simple visual inspection for a substantial change in within-unit outcomes shortly after the intervention starts."

To ensure effectiveness and efficiency, the Purdue Statistical Consulting Service was approached for guidance at the conclusion of data collection. Based off of consultations, the pairwise comparisons and the generalized linear mixed model, $Y_{IJK}=S_I+C_J+(T_K+(CT)_{JK})+ \varepsilon_{IJK}$, where S stood for student, C for course, and T for time (which survey taken), were used for maximum efficiency.

3.8 Chapter Three Summary

This quasi-experimental study was meant to evaluate the effects of a onetime integrated STEM lesson on interest and engagement in secondary students from eighth grade to seniors. Purdue preservice teachers worked diligently to create compelling integrated STEM lessons that fit with the goals and objectives of the Purdue class, *Methods of Integrated STEM Education.* Purdue preservice teachers then taught those lessons in the test site school. In order to evaluate student interest and engagement, the subscales, interest/enjoyment, perceived competence, effort, and value/usefulness of the Intrinsic Motivation Inventory, were utilized.

Four STEM classes from the test site school were used to gather data. Each class implemented a survey (using the above subscales) five times; twice, with one survey following after two separate standard lessons taught by the STEM teacher; once, after the integrated STEM lesson taught by Purdue preservice teachers; then, twice again following two separate standard lessons taught by the STEM teacher. This method allows for a baseline to be established for each student, to identify if the integrated STEM lesson disrupted the baseline, demonstrating an effect. Once all data had been collected, comparison and analysis of data took place.

CHAPTER 4. RESULTS

4.1 Introduction

This chapter is a review of the data and results from this quasi-experimental study. Four separate classes of secondary students were surveyed five times using the Intrinsic Motivation Inventory in order to evaluate interest/motivation. The included classes were: *Introduction to Agriculture, Foods, and Natural Resources* (n=16 students), *Natural Resources* (n=8 students), *General Science* (n=16 students), and *Introduction to Engineering Design* (n=9 students).The survey consisted of four separate subscales: interest/enjoyment, perceived competence, effort/importance, and value/usefulness, all of which were indicators of student interest/motivation (Intrinsic Motivation Inventory, n.d.). In total, the 25 items on the survey used a Likert scale from one to seven, giving the entire survey a total range from 25 to 175.

The research design utilized a multiple baseline methodology (A-A-B-A-A replication), with the intention of comparing the treatment to existing levels of student interest/motivation. During the baseline measurements (A), students were surveyed after the normally planned lesson for that day, meaning that the teacher from each class taught as if no research was happening. However, the treatment lesson (B) was taught by a guest Purdue preservice teacher and focused on integrated STEM principles.

Differences between each repeated measure were then analyzed using Statistical Package for the Social Sciences (SPSS) version 22. First, data were combined from all four classes and analyzed to see if there was an overall effect, then data were analyzed individually per class due to the different content of each class.

4.2 Test of Normality

Tests of normality were conducted in order to ensure normal distribution throughout the data. Normality was measured using the Shapiro-Wilk test as it was best suited for small sample sizes (Shaprio and Wilk, 1965). Normality distributions varied by course. Normality tests of the overall data set, as well as the individual courses, are found in *Table 4.2.1*, significance of $p<.05$ indicates significant deviation from normal distribution.

Table 4.2.1
Tests of Normality

Class	Survey	Shapiro-Wilk		
		Statistic	**df**	**Sig.**
All Combined	Baseline 1	.948	48	.033*
	Baseline 2	.955	45	.080
	Treatment	.949	49	**.033**
	Baseline 3	.952	38	.103
	Baseline 4	.940	33	.068
Intro to Agriculture, Foods, and Natural Resources	Baseline 1	.973	15	.904
	Baseline 2	.953	14	.603
	Treatment	.941	16	.367
	Baseline 3	.953	13	.651
	Baseline 4	.912	11	.257
Natural Resources	Baseline 1	.951	8	.720
	Baseline 2	.868	8	.145
	Treatment	.939	8	.601
	Baseline 3	.835	7	.089
	Baseline 4	.589	6	**.000**
General Science	Baseline 1	.948	16	.453
	Baseline 2	.945	15	.453
	Treatment	.939	16	.338
	Baseline 3	.916	13	.224
	Baseline 4	.959	12	.774
Intro to Engineering Design	Baseline 1	.898	9	.239
	Baseline 2	.912	8	.371
	Treatment	.893	9	.212
	Baseline 3	.921	5	.533
	Baseline 4	.968	4	.827

Note- Values in **bold** are significant.

Ghasemi and Zahediasl (2012) said that, “with large enough sample sizes (>30 or 40), the violation of the normality assumption should not cause major problems” (p. 1). This means that due to the relative lack deviation from normal distribution and an overall sample size of 49, any violations of normality have minimal impact on the results.

4.3 Reliability

After data was collected, Cronbach's Alpha (*Table 4.3.1*) was run on each individual subset of the instrument for each survey in order establish reliability.

Table 4.3.1
Cronbach's Alpha

Subset	**Baseline 1**	**Baseline 2**	**Treatment**	**Baseline 3**	**Baseline 4**
Perceived Competence (N=6 items)	.904	.911	.886	.757	.851
Value/ Usefulness (N=8 items)	.945	.970	.962	.966	.965
Effort/ Importance (N=4 items)	.777	.861	.722	.765	.735
Interest/ Enjoyment (N=7 items)	.934	.930	.881	.883	.924

4.4 Findings

In order to gauge the differences measured between each survey, a generalized linear mixed model comparison of the survey effect (K Matrix) was used. The model used was $Y_{IJK}=S_I+C_J+T_K+(CT)_{JK}+ \varepsilon_{IJK}$, where S stood for student, C for course, and T for time (which survey taken). If the treatment had an effect, then there would be no significant change between surveys one and two, creating a baseline; significant change between two and three, significant change between three and four, showing an increase then decline; then no significant change between four and five, creating another baseline. If this were to happen, it would indicate that the treatment had the anticipated effect. To gauge statistical significance, an alpha coefficient of .05 was used, meaning a value of <.05 was significant. Initially, the study consisted of 69 students, but any student that was unable to take the treatment survey was removed from the data set, reducing participants to 49. Overall student participation noticeably dropped after the treatment survey, as seen below in *Table 4.4.1*:

Table 4.4.1
Overall Descriptive Statistics of Student Participation

		N
Survey	Baseline 1	48
	Baseline 2	45
	Treatment	49
	Baseline 3	38
	Baseline 4	33

First, all of the data from all four classes were evaluated as a whole, as seen below in *Table 4.4.2*.

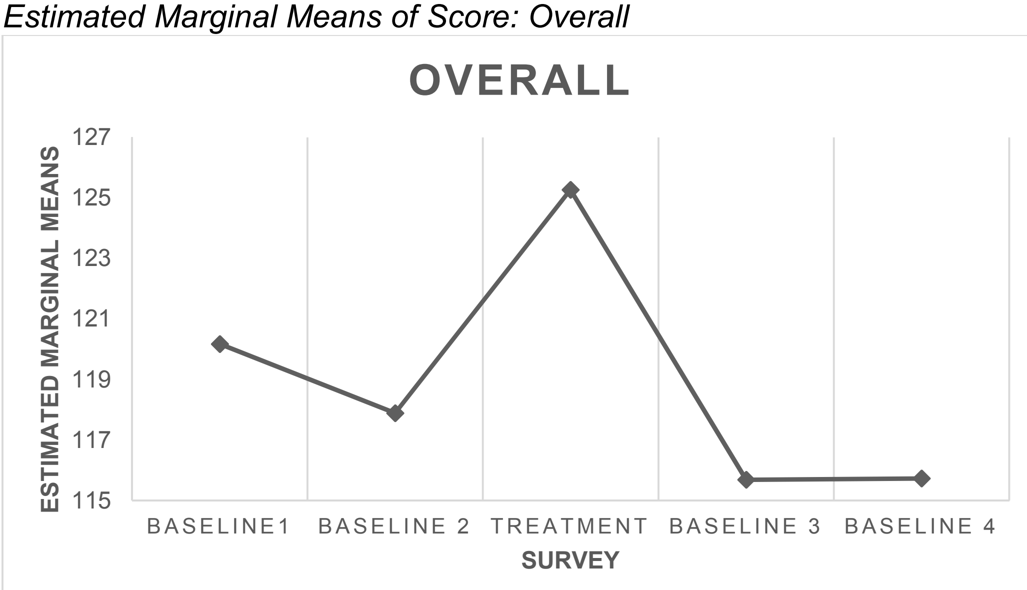
Table 4.4.2
Repeated Measures Contrast Results: Overall

Survey Repeated Contrast			**Dependent Variable Score**
Baseline 1 vs. Baseline 2	Contrast Estimate		2.369
	Hypothesized Value		0
	Difference (Estimate – Hypothesized)		2.369
	Std. Error		6.108
	Sig.		**.699**
	95% Confidence Interval for Difference	Lower Bound	-9.679
		Upper Bound	14.417
Baseline 2 vs. Treatment	Contrast Estimate		-8.020
	Hypothesized Value		0
	Difference (Estimate – Hypothesized)		-8.020
	Std. Error		6.091
	Sig.		**.190**
	95% Confidence Interval for Difference	Lower Bound	-20.034
		Upper Bound	3.994
Treatment vs. Baseline 3	Contrast Estimate		8.432
	Hypothesized Value		0
	Difference (Estimate – Hypothesized)		8.432
	Std. Error		6.518
	Sig.		**.197**
	95% Confidence Interval for Difference	Lower Bound	-4.423
		Upper Bound	21.288
Baseline 3 vs. Baseline 4	Contrast Estimate		-1.626
	Hypothesized Value		0
	Difference (Estimate – Hypothesized)		-1.626
	Std. Error		7.339
	Sig.		**.825**
	95% Confidence Interval for Difference	Lower Bound	-16.101
		Upper Bound	12.850

Based off of this data in *Table 4.4.2*, there was no statistically significant difference between the first and second survey, p=.699. This was expected because the lack of change represents a baseline to compare the treatment to. However, there was only a statistical difference of p=.190 between the means of the second survey and the treatment. This indicates that there was a slight positive change, but it was not statistically significant at the .05 level. There was then again no statistically significant change between the treatment and the third baseline survey (p=.197), but it indicated a decline of interest/motivation. Last, with a p=.825, there was no significant change between the third and fourth baseline surveys, meaning they formed the desired baseline.

Although there was no statistical significance found, the following *Figure 4.4.3* can be used to draw visual conclusions. On the Likert scale of one to seven, the average item score for each respective measurement was roughly 4.80, 4.72, 5.04, 4.64, and 4.64.

Figure 4.4.3
Estimated Marginal Means of Score: Overall



No statistically significant change happened, but the figure (*Figure 4.4.3*) does show that visible change happened during the treatment survey.

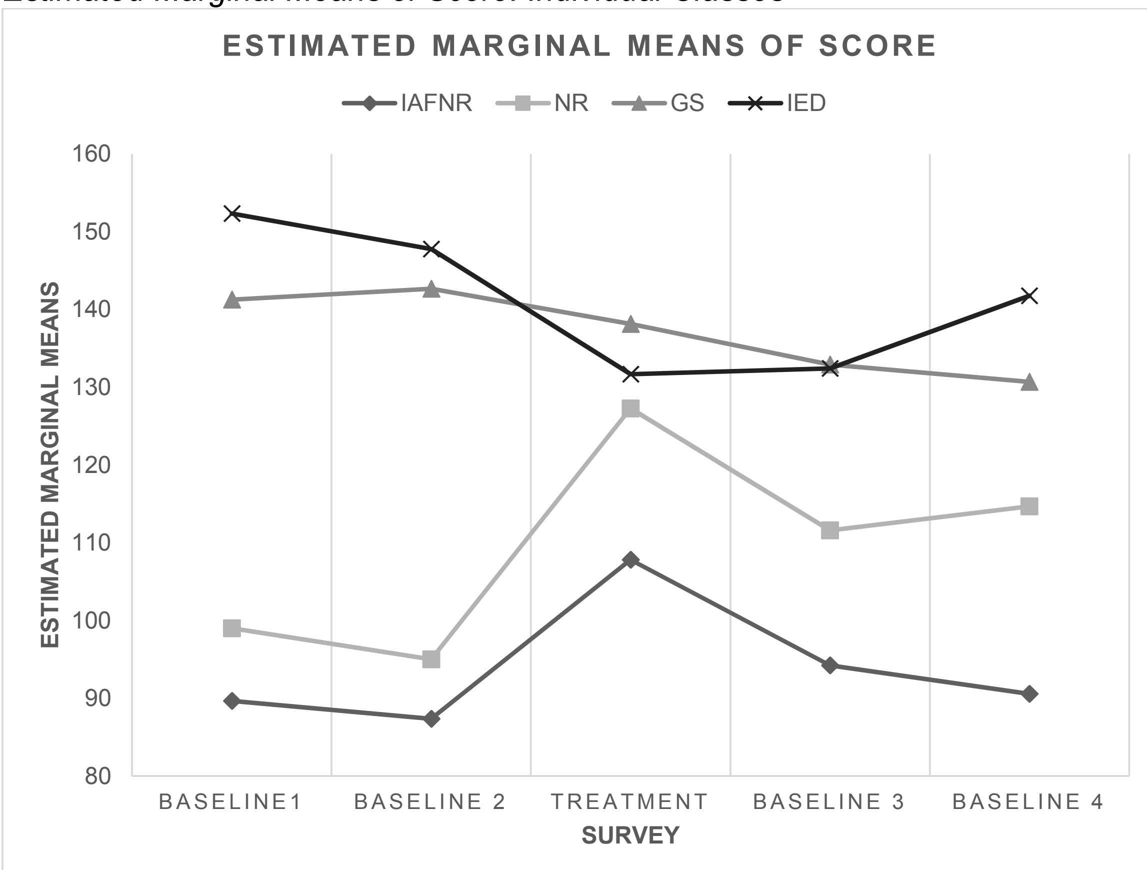
Pairwise comparison of survey effect was then used to evaluate the biggest differences between each survey. Below, in *Table 4.4.4,* the most noticeable changes are in bold.

Table 4.4.4
Pairwise Comparisons: Overall

(I) Survey	(J) Survey	(I-J) Mean Difference	Std. Error	**Sig.[a]**
Baseline 1	Baseline 2	2.369	6.108	0.699
	Treatment	-5.651	5.998	0.347
	Baseline 3	2.781	6.534	0.671
	Baseline 4	1.155	6.882	0.867
Baseline 2	Baseline 1	-2.369	6.108	0.699
	Treatment	-8.02	6.091	**0.190**
	Baseline 3	0.412	6.62	0.950
	Baseline 4	-1.214	6.963	0.862
Treatment	Baseline 1	5.651	5.998	0.347
	Baseline 2	8.02	6.091	**0.190**
	Baseline 3	8.432	6.518	**0.197**
	Baseline 4	6.806	6.867	0.323
Baseline 3	Baseline 1	-2.781	6.534	0.671
	Baseline 2	-0.412	6.62	0.950
	Treatment	-8.432	6.518	**0.197**
	Baseline 4	-1.626	7.339	0.825
Baseline 4	Baseline 1	-1.155	6.882	0.867
	Baseline 2	1.214	6.963	0.862
	Treatment	-6.806	6.867	0.323
	Baseline 3	1.626	7.339	0.825

The pairwise comparison shows no significant change between surveys. However, this represents data from all four classes combined, and after interviewing the participating STEM teachers, it was clear that each class was very different from one another (Refer to section 3.6). Each class must be separately analyzed to see which classes benefitted the most from treatment and which did not. *Figure 4.4.5* below shows that each class did vary, so analysis of individual significance was required.

Figure 4.4.5
Estimated Marginal Means of Score: Individual Classes



<u>KEY</u>

IAFNR- Introduction to Agriculture, Foods, and Natural Resources
NR- Natural Resources
GS- General Science
IED- Introduction to Engineering Design

4.4.1 Introduction to Agriculture, Foods, and Natural Resources Results

Table 4.4.1.1
Repeated Measures Contrast Results: Introduction to Agriculture, Foods, and Natural Resources

Survey Repeated Contrast			Dependent Variable Score
Baseline 1 vs. Baseline 2	Contrast Estimate		2.310
	Hypothesized Value		0
	Difference (Estimate – Hypothesized)		2.310
	Std. Error		11.377
	Sig.		**.840**
	95% Confidence Interval for Difference	Lower Bound	-20.418
		Upper Bound	25.037
Baseline 2 vs. Treatment	Contrast Estimate		-20.455
	Hypothesized Value		0
	Difference (Estimate – Hypothesized)		-20.455
	Std. Error		11.204
	Sig.		**.073**
	95% Confidence Interval for Difference	Lower Bound	-42.837
		Upper Bound	1.927
Treatment vs. Baseline 3	Contrast Estimate		13.582
	Hypothesized Value		0
	Difference (Estimate – Hypothesized)		13.582
	Std. Error		11.431
	Sig.		**.239**
	95% Confidence Interval for Difference	Lower Bound	-9.255
		Upper Bound	36.418
Baseline 3 vs. Baseline 4	Contrast Estimate		3.685
	Hypothesized Value		0
	Difference (Estimate – Hypothesized)		3.685
	Std. Error		12.542
	Sig.		**.770**
	95% Confidence Interval for Difference	Lower Bound	-21.370
		Upper Bound	28.741

Based off of this data from *Table 4.4.1.1*, there was no statistically significant difference between the first and second survey, p=.840. This was expected because the lack of change represents a baseline to compare the treatment to. However, there was only a statistical difference of p=.073 between the second survey and the treatment. This indicates that there was a positive change, but it was not statistically significant. There was then again no statistically significant change between the treatment and the following third baseline survey (p=.239). Last, with a significance of p=.770, there was no significant change between the third and fourth baseline surveys, meaning they formed a stable baseline. On the following page, in *Table 4.4.1.2,* is a pairwise comparison of the survey effect which compares the differences between all surveys taken in the Introduction to Agriculture, Foods, and Natural Resources class.

Table 4.4.1.2
Pairwise Comparisons: Introduction to Agriculture, Foods, and Natural Resources

(I) Survey	(J) Survey	(I-J) Mean Difference	Std. Error	**Sig.[a]**
Baseline 1	Baseline 2	2.31	11.377	0.840
	Treatment	-18.146	11.003	**0.104**
	Baseline 3	-4.564	11.601	0.695
	Baseline 4	-0.879	12.153	0.943
Baseline 2	Baseline 1	-2.31	11.377	0.840
	Treatment	-20.455	11.204	**0.073**
	Baseline 3	-6.874	11.792	0.562
	Baseline 4	-3.188	12.335	0.797
Treatment	Baseline 1	18.146	11.003	0.104
	Baseline 2	20.455	11.204	**0.073**
	Baseline 3	13.582	11.431	0.239
	Baseline 4	17.267	11.991	**0.155**
Baseline 3	Baseline 1	4.564	11.601	0.695
	Baseline 2	6.874	11.792	0.562
	Treatment	-13.582	11.431	0.239
	Baseline 4	3.685	12.542	0.770
Baseline 4	Baseline 1	0.879	12.153	0.943
	Baseline 2	3.188	12.335	0.797
	Treatment	-17.267	11.991	**0.155**
	Baseline 3	-3.685	12.542	0.770

The following *Figure 4.4.1.3* represents the visual change, and *Table 4.4.1.4* represents the average scores for each survey, as well as the average score for each item answered. Again, although not statistically significant, it appears that the treatment may have some influence on student interest/motivation.

Figure 4.4.1.3
Estimated Marginal Means of Score: Introduction to Agriculture, Foods, and Natural Resources

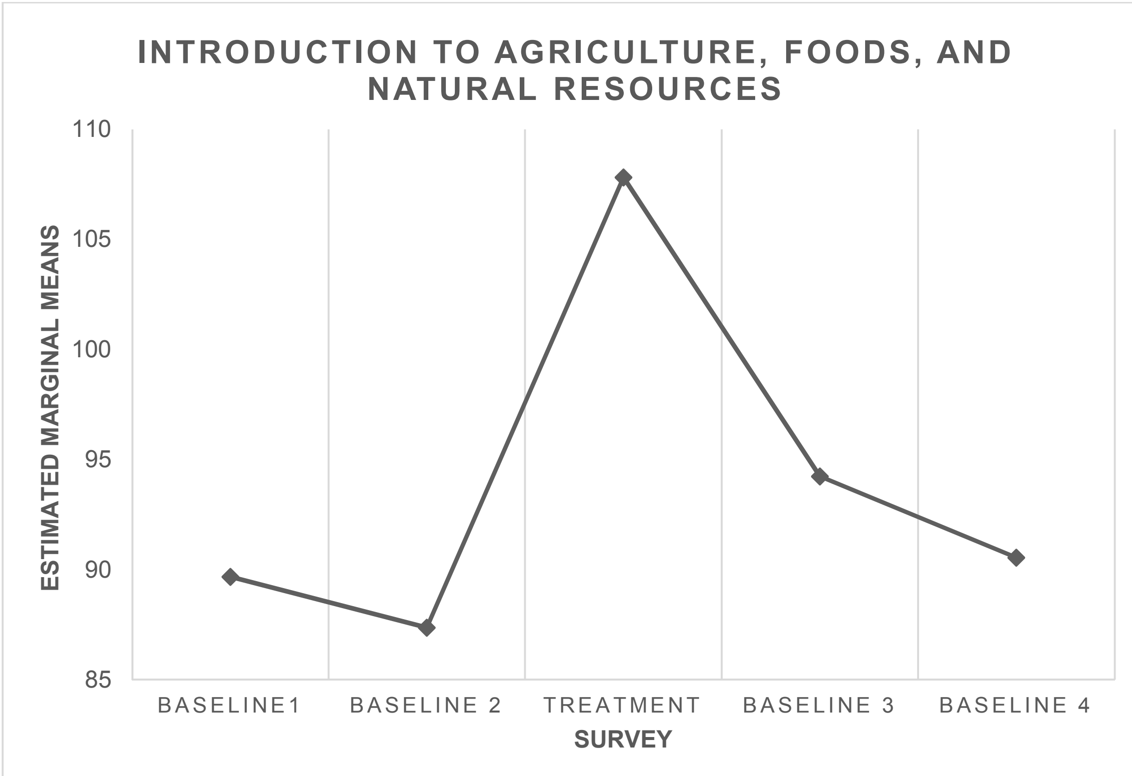


Table 4.4.1.4
Estimated Marginal Means: Introduction to Agriculture, Foods, and Natural Resources

Survey	Total Mean (25-175)	Item Mean (1-7)	Standard Error	Interval	
				Lower Bound	Upper Bound
Baseline 1	89.667	3.586	7.905	73.875	105.458
Baseline 2	87.357	3.494	8.182	71.012	103.703
Treatment	107.81	4.312	7.654	92.523	123.102
Baseline 3	94.231	3.769	8.491	77.268	111.193
Baseline 4	90.545	3.621	9.231	72.105	108.986

4.4.2 Natural Resources Results

Table 4.4.2.1
Repeated Measures Contrast Results: Natural Resources

Survey Repeated Contrast			**Dependent Variable Score**
Baseline 1 vs. Baseline 2	Contrast Estimate		4.000
	Hypothesized Value		0
	Difference (Estimate – Hypothesized)		4.000
	Std. Error		16.222
	Sig.		**.807**
	95% Confidence Interval for Difference	Lower Bound	-29.043
		Upper Bound	37.043
Baseline 2 vs. Treatment	Contrast Estimate		-32.250
	Hypothesized Value		0
	Difference (Estimate – Hypothesized)		-32.250
	Std. Error		16.222
	Sig.		**.05**
	95% Confidence Interval for Difference	Lower Bound	-65.293
		Upper Bound	.793
Treatment vs. Baseline 3	Contrast Estimate		15.679
	Hypothesized Value		0
	Difference (Estimate – Hypothesized)		15.679
	Std. Error		16.791
	Sig.		**.357**
	95% Confidence Interval for Difference	Lower Bound	-18.524
		Upper Bound	49.881
Baseline 3 vs. Baseline 4	Contrast Estimate		-3.095
	Hypothesized Value		0
	Difference (Estimate – Hypothesized)		-3.095
	Std. Error		18.050
	Sig.		**.865**
	95% Confidence Interval for Difference	Lower Bound	-39.862
		Upper Bound	33.671

Based off of this data from *Table 4.4.2.1*, there was no statistically significant difference between the first and second survey, p=.807. This was expected because the lack of change represents a baseline to compare the treatment to. There was a statistical difference of p=.05 between the second survey and the treatment. This indicates that there was a positive change, and it was statistically significant. There was then again no statistically significant change between the treatment and the following third baseline survey (p=.357). Last, with a significance of p=.865, there was no significant change between the third and fourth baseline surveys, meaning they formed the desired baseline. Below, in *Table 4.4.2.2,* is a pairwise comparison of the survey effect which compares the differences between all surveys taken in the Natural Resources class.

Table 4.4.2.2
Pairwise Comparisons: Natural Resources

(I) Survey	(J) Survey	(I-J) Mean Difference	Std. Error	**Sig.[a]**
Baseline 1	Baseline 2	4	16.222	0.807
	Treatment	-28.25	16.222	**0.091**
	Baseline 3	-12.571	16.791	0.460
	Baseline 4	-15.667	17.521	0.378
Baseline 2	Baseline 1	-4	16.222	0.807
	Treatment	-32.25	16.222	**0.050**
	Baseline 3	-16.571	16.791	0.331
	Baseline 4	-19.667	17.521	0.270
Treatment	**Baseline 1**	28.25	16.222	**0.091**
	Baseline 2	32.25	16.222	**0.055**
	Baseline 3	15.679	16.791	0.357
	Baseline 4	12.583	17.521	0.478
Baseline 3	Baseline 1	12.571	16.791	0.460
	Baseline 2	16.571	16.791	0.331
	Treatment	-15.679	16.791	0.357
	Baseline 4	-3.095	18.05	0.865
Baseline 4	Baseline 1	15.667	17.521	0.378
	Baseline 2	19.667	17.521	0.270
	Treatment	-12.583	17.521	0.478
	Baseline 3	3.095	18.05	0.865

The following *Figure 4.4.2.3* represents the visual change, and *Table 4.4.2.4* represents the average scores for each survey, as well as the average score for each item answered. Student interest/motivation significantly spiked during the treatment in comparison to the previous baseline lesson.

Figure 4.4.2.3
Estimated Marginal Means of Score: Natural Resources

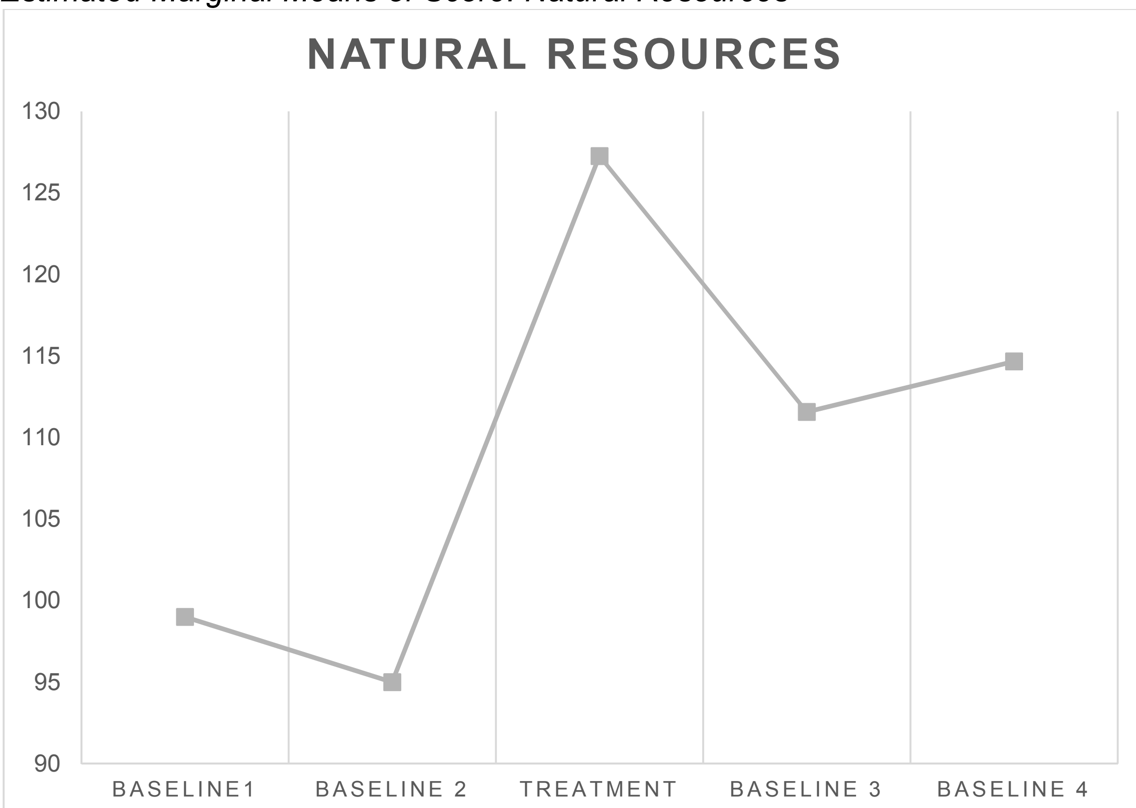


Table 4.4.2.4
Estimated Marginal Means: Natural Resources

Survey	Total Mean (25-175)	Item Mean (1-7)	Standard Error	Interval	
				Lower Bound	Upper Bound
Baseline 1	99.000	3.960	11.471	75.635	122.365
Baseline 2	95.000	3.800	11.471	71.635	118.365
Treatment	127.25	5.090	11.471	103.885	150.615
Baseline 3	111.57	4.462	12.262	86.594	136.549
Baseline 4	114.67	4.586	13.245	87.687	141.646

4.4.3 General Science Results

Table 4.4.3.1
Repeated Measures Contrast Results: General Science

Survey Repeated Contrast			Dependent Variable Score
Baseline 1 vs. Baseline 2	Contrast Estimate		-1.417
	Hypothesized Value		0
	Difference (Estimate – Hypothesized)		-1.417
	Std. Error		8.961
	Sig.		**0.875**
	95% Confidence Interval for Difference	Lower Bound	-19.303
		Upper Bound	16.47
Baseline 2 vs. Treatment	Contrast Estimate		4.542
	Hypothesized Value		0
	Difference (Estimate – Hypothesized)		4.542
	Std. Error		8.961
	Sig.		**0.614**
	95% Confidence Interval for Difference	Lower Bound	-13.345
		Upper Bound	22.428
Treatment vs. Baseline 3	Contrast Estimate		5.202
	Hypothesized Value		0
	Difference (Estimate – Hypothesized)		5.202
	Std. Error		9.31
	Sig.		**0.578**
	95% Confidence Interval for Difference	Lower Bound	-13.381
		Upper Bound	23.785
Baseline 3 vs. Baseline 4	Contrast Estimate		2.256
	Hypothesized Value		0
	Difference (Estimate – Hypothesized)		2.256
	Std. Error		9.982
	Sig.		**0.822**
	95% Confidence Interval for Difference	Lower Bound	-17.667
		Upper Bound	22.18

Based off of this data from *Table 4.4.3.1*, there was no statistically significant difference between the first and second survey, p=.875. This was expected because the lack of change represents a baseline to compare the treatment to. However, there was only a statistical difference of *p*=.614 between the second survey and the treatment. This indicates that there was so statistically significant change. There was then again no statistically significant change between the treatment and the following third baseline survey (*p*=.578). Last, with a significance of *p*=.822, there was no significant change between the third and fourth baseline surveys, meaning they formed the desired baseline. Below, in *Table 4.4.3.2,* is a pairwise comparison of the survey effect which compares the differences between all surveys taken in the *General Science* class.

Table 4.4.3.2
Pairwise Comparisons: General Science

(I) Survey	(J) Survey	(I-J) Mean Difference	Std. Error	**Sig.[a]**
Baseline 1	Baseline 2	-1.417	8.961	0.875
	Treatment	3.125	8.815	0.724
	Baseline 3	8.327	9.31	0.374
	Baseline 4	10.583	9.522	0.270
Baseline 2	Baseline 1	1.417	8.961	0.875
	Treatment	4.542	8.961	0.614
	Baseline 3	9.744	9.448	0.306
	Baseline 4	12	9.657	0.218
Treatment	Baseline 1	-3.125	8.815	0.724
	Baseline 2	-4.542	8.961	0.614
	Baseline 3	5.202	9.31	0.578
	Baseline 4	7.458	9.522	0.436
Baseline 3	Baseline 1	-8.327	9.31	0.374
	Baseline 2	-9.744	9.448	0.306
	Treatment	-5.202	9.31	0.578
	Baseline 4	2.256	9.982	0.822
Baseline 4	Baseline 1	-10.583	9.522	0.270
	Baseline 2	-12	9.657	0.218
	Treatment	-7.458	9.522	0.436
	Baseline 3	-2.256	9.982	0.822

The following *Figure 4.4.3.3* represents the visual change, and *Table 4.4.3.4* represents the average scores for each survey, as well as the average score for each item answered. Overall, there is a notable downward trend in the data.

Figure 4.4.3.3
Estimated Marginal Means of Score: General Science

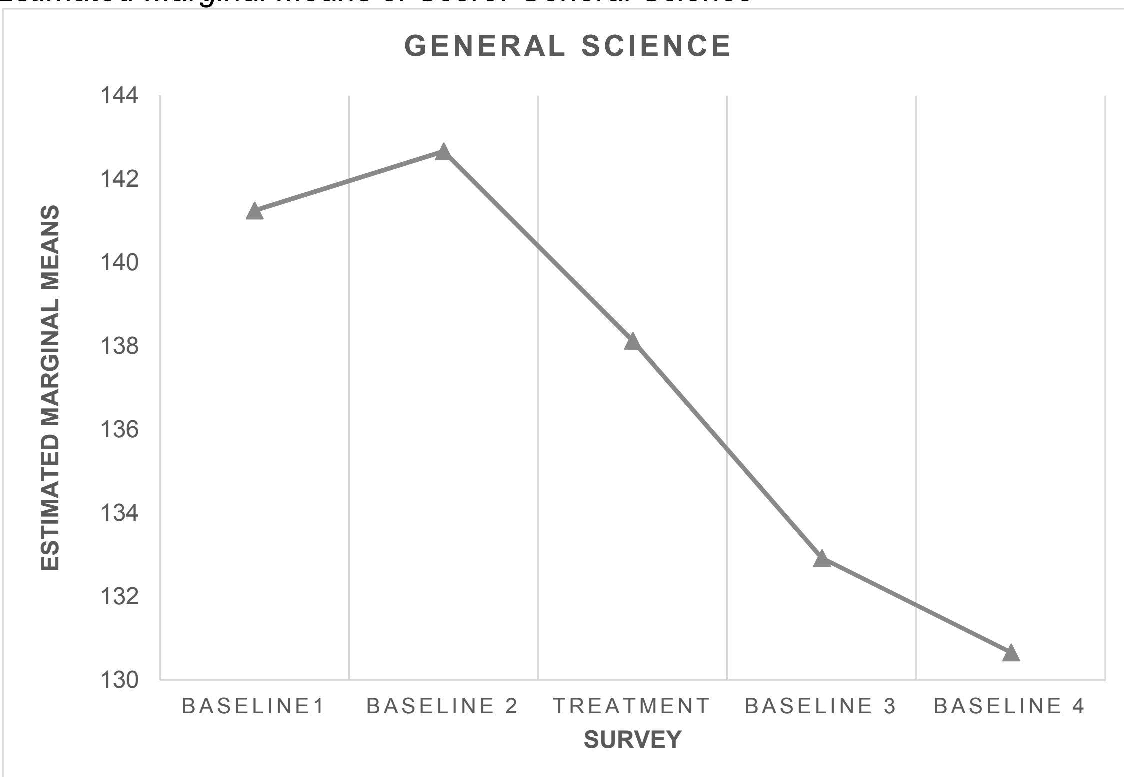


Table 4.4.3.4
Estimated Marginal Means: General Science

Survey	Total Mean (25-175)	Item Mean (1-7)	Standard Error	Interval	
				Lower Bound	Upper Bound
Baseline 1	141.250	5.650	6.233	128.808	153.692
Baseline 2	142.667	5.706	6.438	129.817	155.517
Treatment	138.125	5.525	6.233	125.683	150.567
Baseline 3	132.923	5.316	6.915	119.120	146.726
Baseline 4	130.667	5.226	7.198	116.300	145.033

4.4.4 Introduction to Engineering Design Results

Table 4.4.4.1

Repeated Measures Contrast Results: Introduction to Engineering Design

Survey Repeated Contrast			Dependent Variable
			Score
Baseline 1 vs. Baseline 2	Contrast Estimate		4.583
	Hypothesized Value		0
	Difference (Estimate – Hypothesized)		4.583
	Std. Error		11.775
	Sig.		**0.7**
	95% Confidence Interval for Difference	Lower Bound	-19.465
		Upper Bound	28.632
Baseline 2 vs. Treatment	Contrast Estimate		16.083
	Hypothesized Value		0
	Difference (Estimate – Hypothesized)		16.083
	Std. Error		11.775
	Sig.		**0.182**
	95% Confidence Interval for Difference	Lower Bound	-7.965
		Upper Bound	40.132
Treatment vs. Baseline 3	Contrast Estimate		-0.733
	Hypothesized Value		0
	Difference (Estimate – Hypothesized)		-0.733
	Std. Error		13.517
	Sig.		**0.957**
	95% Confidence Interval for Difference	Lower Bound	-28.338
		Upper Bound	26.871
Baseline 3 vs. Baseline 4	Contrast Estimate		-9.35
	Hypothesized Value		0
	Difference (Estimate – Hypothesized)		-9.35
	Std. Error		16.256
	Sig.		**0.569**
	95% Confidence Interval for Difference	Lower Bound	-42.549
		Upper Bound	23.849

Based off of this data from *Table 4.4.4.1*, there was no statistically significant difference between the first and second survey, p=.7. This was expected because the lack of change represents a baseline to compare the treatment to. However, there was a statistical difference of *p*=.182 between the second survey and the treatment. While not statistically significant, the change happens in the negative direction, the opposite of the desired effect. There was then again no statistically significant change between the treatment and the following third baseline survey (*p*=.957). Last, with a significance of *p*=.569, there was no significant change between the third and fourth baseline surveys, meaning they formed the desired baseline. Below, in *Table 4.4.4.2,* is a pairwise comparison of the survey effect which compares the differences between all surveys taken in the Introduction to Engineering Design class.

Table 4.4.4.2
Pairwise Comparisons: Introduction to Engineering Design

(I) Survey	(J) Survey	(I-J) Mean Difference	Std. Error	**Sig.[a]**
Baseline 1	Baseline 2	4.583	11.775	0.700
	Treatment	20.667	11.424	**0.080**
	Baseline 3	19.933	13.517	**0.151**
	Baseline 4	10.583	14.562	0.473
Baseline 2	Baseline 1	-4.583	11.775	0.700
	Treatment	16.083	11.775	**0.182**
	Baseline 3	15.35	13.815	0.275
	Baseline 4	6	14.84	**0.689**
Treatment	**Baseline 1**	-20.667	11.424	**0.080**
	Baseline 2	-16.083	11.775	**0.182**
	Baseline 3	-0.733	13.517	0.957
	Baseline 4	-10.083	14.562	0.494
Baseline 3	**Baseline 1**	-19.933	13.517	**0.151**
	Baseline 2	-15.35	13.815	0.275
	Treatment	0.733	13.517	0.957
	Baseline 4	-9.35	16.256	0.569
Baseline 4	Baseline 1	-10.583	14.562	0.473
	Baseline 2	-6	14.84	0.689
	Treatment	10.083	14.562	0.494
	Baseline 3	9.35	16.256	0.569

The following *Figure 4.4.4.3* represents the visual change, and *Table 4.4.4.4* represents the average scores for each survey, as well as the average score for each item answered. Overall, the treatment had the opposite of the desired effect.

Figure 4.4.4.3
Estimated Marginal Means of Score: Introduction to Engineering Design

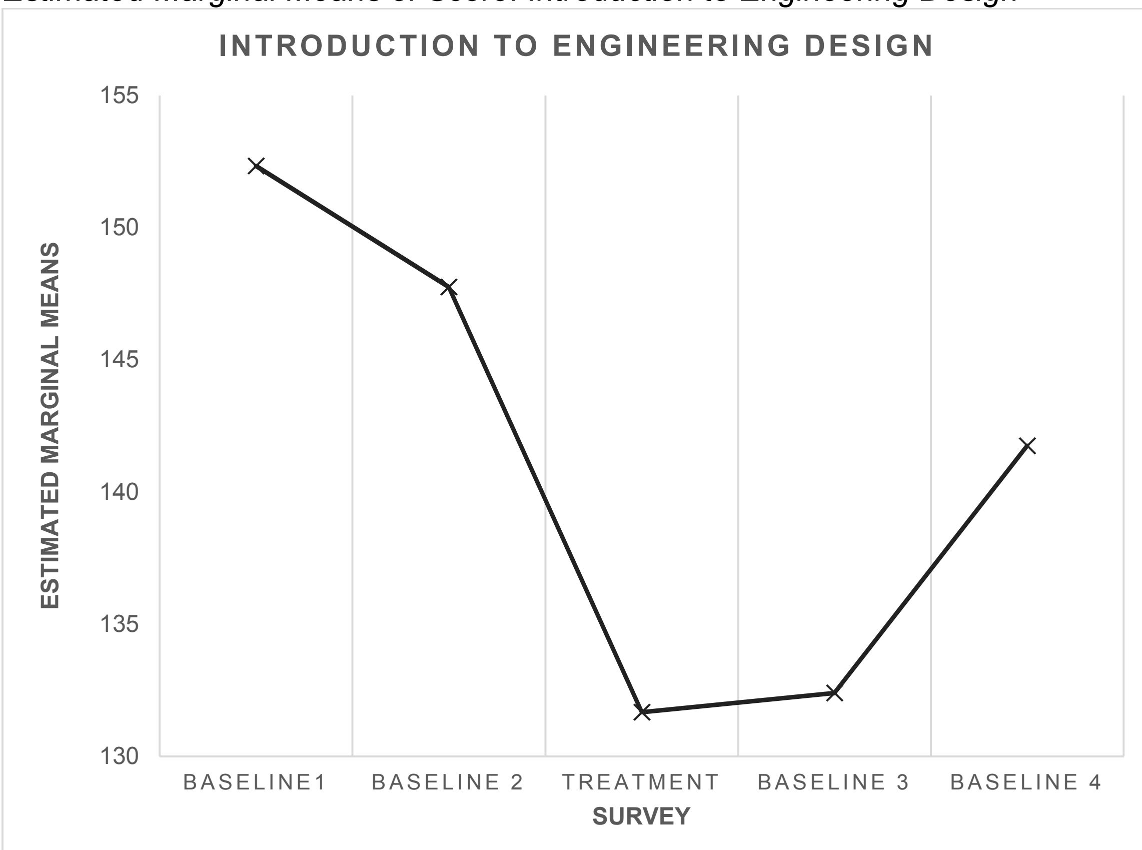


Table 4.4.4.4
Estimated Marginal Means: Introduction to Engineering Design

Survey	**Total Mean (25-175)**	**Item Mean (1-7)**	**Standard Error**	**Interval**	
				Lower Bound	Upper Bound
Baseline 1	152.333	6.093	8.078	135.836	168.830
Baseline 2	147.750	5.910	8.568	130.252	165.248
Treatment	131.667	5.266	8.078	115.170	148.164
Baseline 3	132.400	5.296	10.837	110.267	154.533
Baseline 4	141.750	5.670	12.117	117.005	166.495

4.5 Effect Size

Cohen's d and the effect size correlation were then applied to all four STEM classrooms, comparing each measure to the next (ex: baseline one vs baseline two). *Table 4.5.1* shows the effect size for each classroom.

Table 4.5.1
Cohen's d Comparison of Each Measure

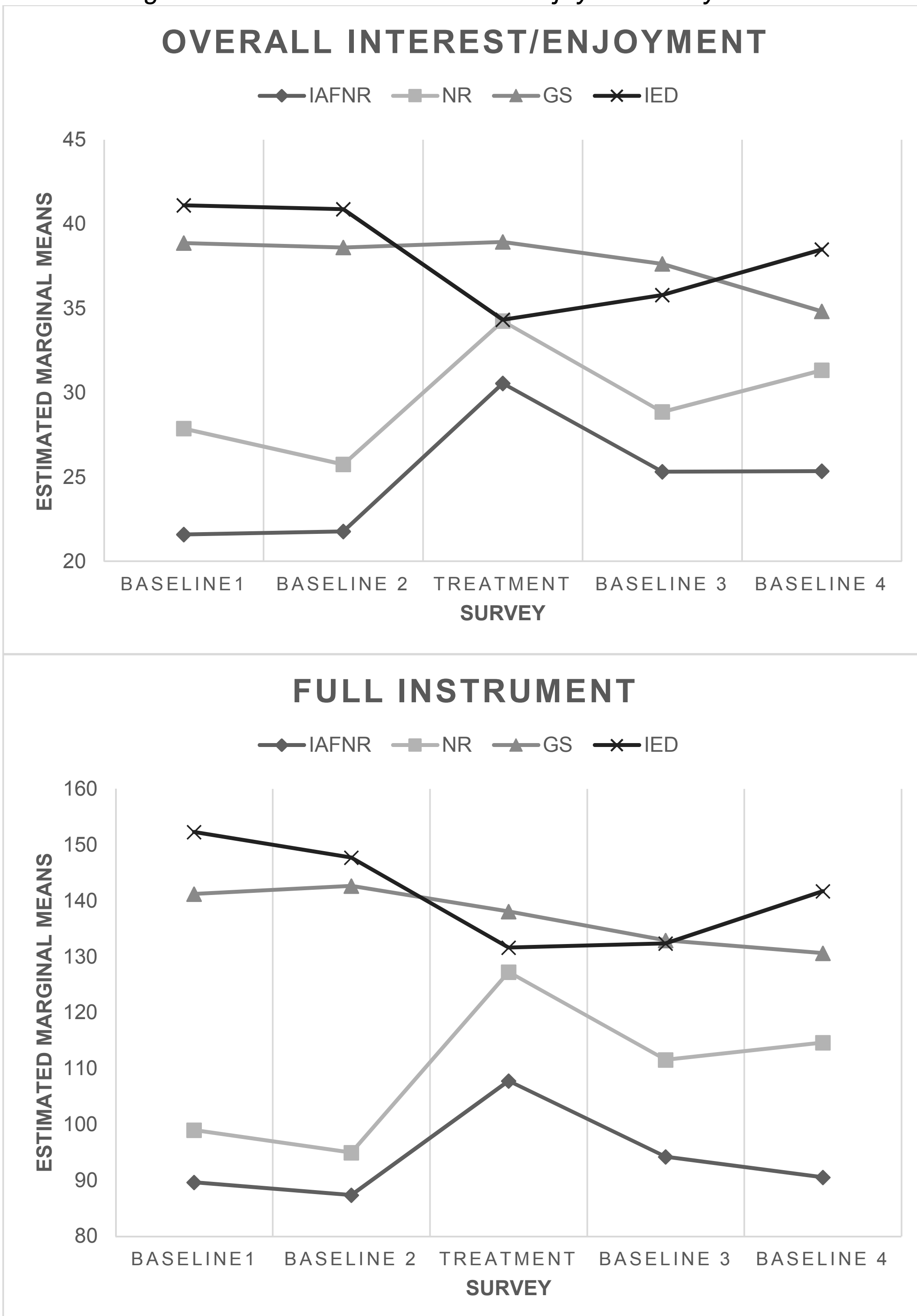
Course	Measure Comparisons	Cohen's *d*	Effect-Size *r*
Introduction to Agriculture, Foods, and Natural Resources	Baseline 1 vs Baseline 2	0.287	0.137
	Baseline 2 vs Treatment	2.580	0.791
	Treatment vs Baseline 3	-1.680	0.643
	Baseline 3 vs Baseline 4	-0.415	0.203
Natural Resources	Baseline 1 vs Baseline 2	0.348	0.171
	Baseline 2 vs Treatment	2.810	0.814
	Treatment vs Baseline 3	-1.320	0.551
	Baseline 3 vs Baseline 4	-0.242	0.120
General Science	Baseline 1 vs Baseline 2	0.223	0.111
	Baseline 2 vs Treatment	0.716	0.337
	Treatment vs Baseline 3	0.790	0.367
	Baseline 3 vs Baseline 4	-0.319	0.157
Introduction to Engineering Design	Baseline 1 vs Baseline 2	0.550	0.265
	Baseline 2 vs Treatment	1.930	0.694
	Treatment vs Baseline 3	-0.076	0.038
	Baseline 3 vs Baseline 4	0.813	0.376

4.6 Interest/Enjoyment Subset

The given survey was a variation of the Intrinsic Motivation Inventory. It was made up of four subsets all relevant to interest: perceived competence, value/usefulness, effort/importance, and interest/enjoyment. The most pertinent of the subsets however, was interest/enjoyment because it specifically aligned with the overall goal of interest and engagement. This section analyzed any significant differences that may have been encountered within the interest/enjoyment subset. However, as seen in the figures (*Figure 4.6.1*) on the following page, there are minimal differences when comparing the interest/enjoyment subset to the original full instrument of the four combined subsets. It is visually clear that only the classes, *Introduction to Foods, Agriculture, and Natural Resources; Natural Resources*; *and Introduction to Engineering Design* show signs of potentially significant change, while *General Science* is more constant. (Note: The scales on the following figures are different because the interest/enjoyment subset score ranged from 7-49, while the full instrument ranged from 25-175. Still, they both follow similar trends.)

Figure 4.6.1

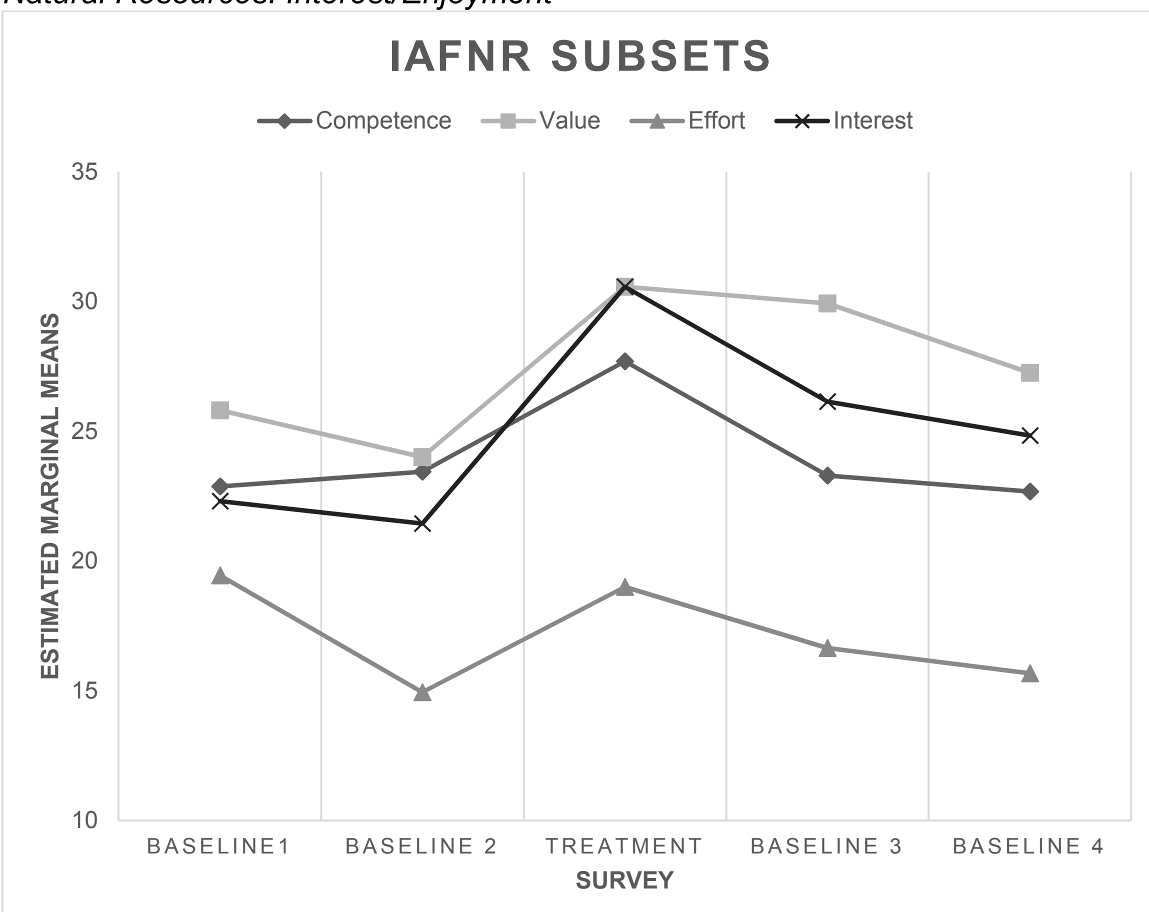
Estimated Marginal Means of Score: Interest/Enjoyment Only VS Full Instrument



4.6.1 Introduction to Agriculture, Foods, and Natural Resources: Interest/Enjoyment Results

Beginning with the analysis of the *Introduction to Agriculture, Foods, and Natural Resources* class, *Figure 4.6.1.1* below shows that there was some variation between each subset with interest/enjoyment encountering the most change.

Figure 4.6.1.1
Estimated Marginal Means of Score: Introduction to Agriculture, Foods, and Natural Resources: Interest/Enjoyment



The pairwise comparison (*Table 4.6.1.2)* was then run to check for statistically significant change between the surveys.

Table 4.6.1.2
Pairwise Comparisons: Introduction to Agriculture, Foods, and Natural Resources: Interest/Enjoyment

(I) Survey	(J) Survey	(I-J) Mean Difference	Std. Error	**Sig.[a]**
Baseline 1	Baseline 2	-0.186	3.946	0.963
	Treatment	-8.963*	3.816	**0.022**
	Baseline 3	-3.631	4.024	0.370
	Baseline 4	-3.764	4.215	0.375
Baseline 2	Baseline 1	0.186	3.946	0.963
	Treatment	-8.777*	3.886	**0.027**
	Baseline 3	-3.445	4.09	0.403
	Baseline 4	-3.578	4.278	0.406
Treatment	**Baseline 1**	8.963*	3.816	**0.022**
	Baseline 2	8.777*	3.886	**0.027**
	Baseline 3	5.332	3.965	0.183
	Baseline 4	5.199	4.159	0.216
Baseline 3	Baseline 1	3.631	4.024	0.370
	Baseline 2	3.445	4.09	0.403
	Treatment	-5.332	3.965	0.183
	Baseline 4	-0.133	4.35	0.976
Baseline 4	Baseline 1	3.764	4.215	0.375
	Baseline 2	3.578	4.278	0.406
	Treatment	-5.199	4.159	0.216
	Baseline 3	0.133	4.35	0.976

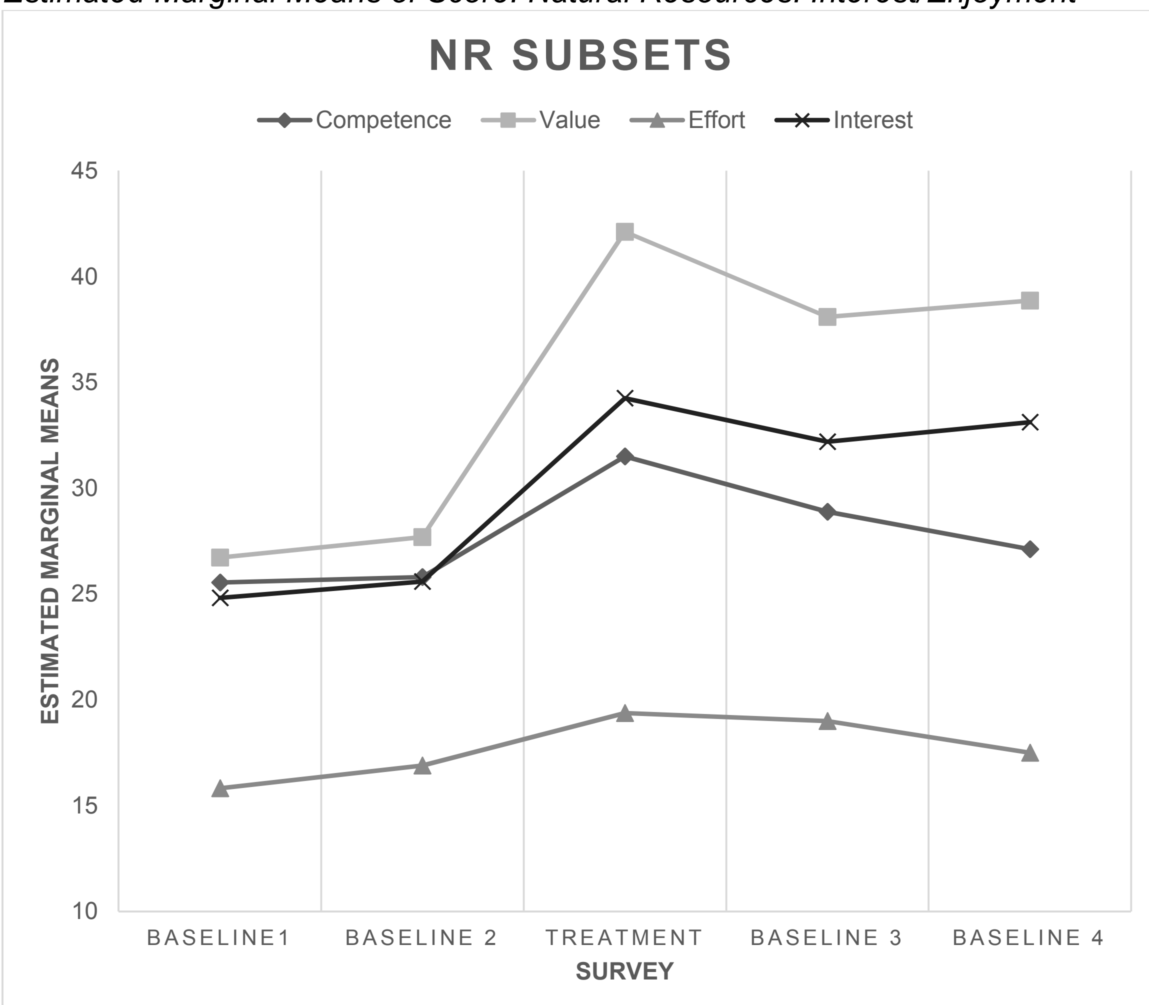
Note- Values in **bold** are significant.

According to the pairwise comparison, there was a significant increase in interest/enjoyment when comparing the treatment to the first (p=.022) and the second baseline (p=.027). Then, while not statistically significant, the p=.183 difference between the treatment and baseline three signify a decline after the treatment.

4.6.2 Natural Resources: Interest/Enjoyment

Analysis of the *Natural Resources* class has shown similar results to the previous class. *Figure 4.6.2.1* below shows that the interest/enjoyment subset encountered change, and value/usefulness encountered the most change. However, only interest/enjoyment was analyzed.

Figure 4.6.2.1
Estimated Marginal Means of Score: Natural Resources: Interest/Enjoyment



The pairwise comparison (*Table 4.6.2.2)* was then run to check for statistically significant change in interest/enjoyment between the surveys.

Table 4.6.2.2
Estimated Marginal Means of Score: Natural Resources: Interest/Enjoyment

(I) Survey	(J) Survey	(I-J) Mean Difference	Std. Error	**Sig.[a]**
Baseline 1	Baseline 2	2.125	4.006	0.599
	Treatment	-6.375	4.006	0.121
	Baseline 3	-0.982	4.147	0.814
	Baseline 4	-3.458	4.327	0.430
Baseline 2	Baseline 1	-2.125	4.006	0.599
	Treatment	-8.500*	4.006	**0.042**
	Baseline 3	-3.107	4.147	0.459
	Baseline 4	-5.583	4.327	0.206
Treatment	Baseline 1	6.375	4.006	0.121
	Baseline 2	8.500*	4.006	**0.042**
	Baseline 3	5.393	4.147	0.203
	Baseline 4	2.917	4.327	0.505
Baseline 3	Baseline 1	0.982	4.147	0.814
	Baseline 2	3.107	4.147	0.459
	Treatment	-5.393	4.147	0.203
	Baseline 4	-2.476	4.457	0.582
Baseline 4	Baseline 1	3.458	4.327	0.430
	Baseline 2	5.583	4.327	0.206
	Treatment	-2.917	4.327	0.505
	Baseline 3	2.476	4.457	0.582

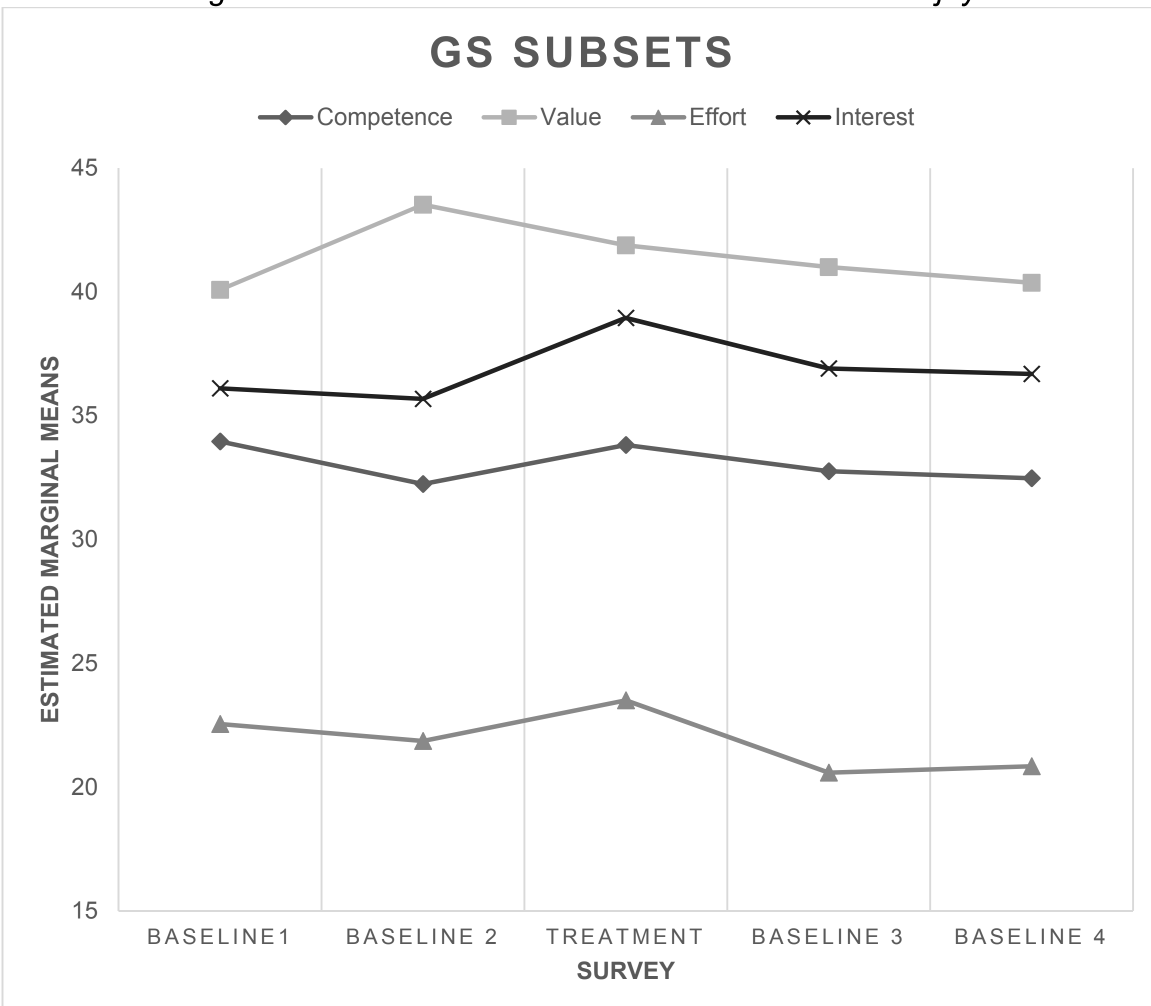
Note- Values in **bold** are significant.

According to the pairwise comparison, there was a significant increase in interest/enjoyment when comparing the treatment to the second baseline (p=.042). Then, while not statistically significant, the p=.203 difference between the treatment and baseline three signify a decline after the treatment.

4.6.3 General Science: Interest Enjoyment

Analysis of the *General Science* class has shown consistent results across all five surveys for all subsets. *Figure 4.6.3.1* below shows that the interest/enjoyment subset stayed relatively constant but with a very slight peak during treatment. Only interest/enjoyment was analyzed.

Figure 4.6.3.1
Estimated Marginal Means of Score: General Science: Interest/Enjoyment



The pairwise comparison (*Table 4.6.3.2)* was then run to check for statistically significant change in interest/enjoyment between the surveys.

Table 4.6.3.2
Estimated Marginal Means of Score: General Science: Interest/Enjoyment

(I) Survey	(J) Survey	(I-J) Mean Difference	Std. Error	**Sig.[a]**
Baseline 1	Baseline 2	.275	2.975	.927
	Treatment	-.063	2.927	.983
	Baseline 3	1.232	3.029	.686
	Baseline 4	4.057	3.242	.215
Baseline 2	Baseline 1	-.275	2.975	.927
	Treatment	-.337	2.975	.910
	Baseline 3	.957	3.076	.757
	Baseline 4	3.782	3.286	.254
Treatment	Baseline 1	.063	2.927	.983
	Baseline 2	.337	2.975	.910
	Baseline 3	1.295	3.029	.670
	Baseline 4	4.119	3.242	.208
Baseline 3	Baseline 1	-1.232	3.029	.686
	Baseline 2	-.957	3.076	.757
	Treatment	-1.295	3.029	.670
	Baseline 4	2.825	3.335	.400
Baseline 4	Baseline 1	-4.057	3.242	.215
	Baseline 2	-3.782	3.286	.254
	Treatment	-4.119	3.242	.208
	Baseline 3	-2.825	3.335	.400

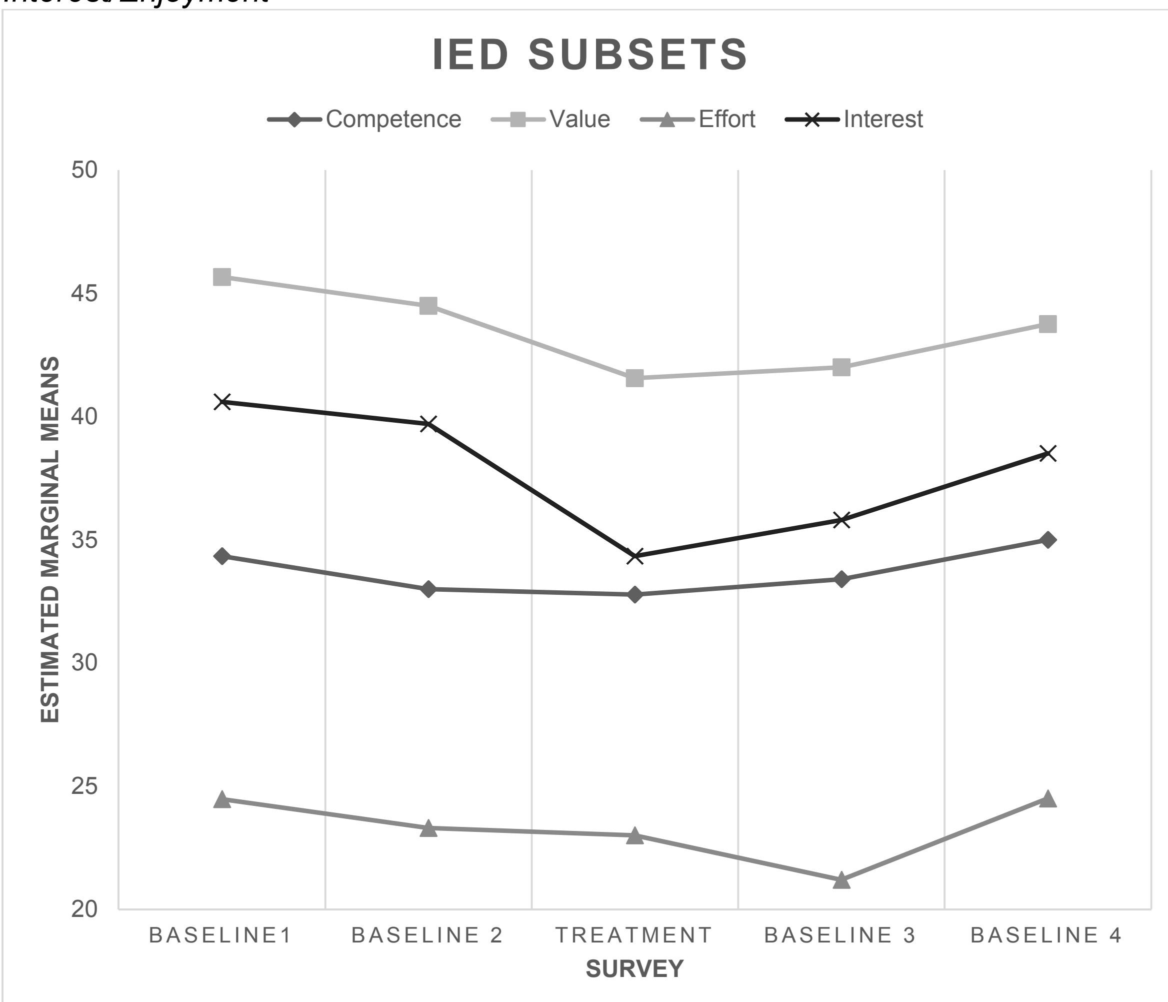
Note- Values in **bold** are significant (No significance in this table).

According to the pairwise comparison, there was no significant difference in interest/enjoyment between any of the surveys.

4.6.4 Introduction to Engineering Design: Interest/Enjoyment

Analysis of the *Introduction to Engineering Design* class has shown consistent results across all five surveys for all subsets. *Figure 4.6.4.1* below shows that the interest/enjoyment subset stayed relatively constant but with a slight decline during treatment. Only interest/enjoyment was analyzed.

Figure 4.6.4.1
Estimated Marginal Means of Score: Introduction to Engineering Design: Interest/Enjoyment



The pairwise comparison (*Table 4.6.4.2)* was then run to check for statistically significant change in interest/enjoyment between the surveys.

Table 4.6.4.2
Estimated Marginal Means of Score: Introduction to Engineering Design: Interest/Enjoyment

(I) Survey	(J) Survey	(I-J) Mean Difference	Std. Error	**Sig.[a]**
Baseline 1	Baseline 2	0.236	4.04	0.954
	Treatment	6.778	3.919	0.094
	Baseline 3	5.311	4.637	0.261
	Baseline 4	2.611	4.996	0.605
Baseline 2	Baseline 1	-0.236	4.04	0.954
	Treatment	6.542	4.04	0.116
	Baseline 3	5.075	4.74	0.293
	Baseline 4	2.375	5.091	0.644
Treatment	Baseline 1	-6.778	3.919	0.094
	Baseline 2	-6.542	4.04	0.116
	Baseline 3	-1.467	4.637	0.754
	Baseline 4	-4.167	4.996	0.411
Baseline 3	Baseline 1	-5.311	4.637	0.261
	Baseline 2	-5.075	4.74	0.293
	Treatment	1.467	4.637	0.754
	Baseline 4	-2.7	5.577	0.632
Baseline 4	Baseline 1	-2.611	4.996	0.605
	Baseline 2	-2.375	5.091	0.644
	Treatment	4.167	4.996	0.411
	Baseline 3	2.7	5.577	0.632

Note- Values in **bold** are significant (No significance in this table).

According to the pairwise comparison, there was no significant difference in interest/enjoyment between any of the surveys. However, while not significant, the difference between baseline one and the treatment (*p*=.094), and between baseline two and the treatment (*p*=.116) show a decrease in interest/enjoyment during the treatment.

4.7 Chapter Four Summary

After conducting tests of normality, data were analyzed. There were variations in each of the four independent participating classrooms, so individual analyses were conducted on the Intrinsic Motivation Inventory instrument and then also the Interest/Enjoyment subset for each class. In order to evaluate change in student interest/motivation, a multiple baseline method was used for data collection (A-A-B-A-A). Students took the survey a total of five times, twice during traditional lessons taught by their normal teacher (traditional meaning whatever the lesson already scheduled was; as if no research was happening), one after an integrated STEM lesson taught by a guest Purdue preservice teacher, then twice more after traditional lessons taught by their teacher. To analyze, the generalized linear mixed model $Y_{IJK}=S_I+C_J+T_K+(CT)_{JK}+\varepsilon_{IJK}$, visual figure observations, and pairwise comparisons were used identify the most significant changes during the series of surveys (p values <.05 considered significant).

The null hypothesis, H_0: the implementation of an integrated science, technology, engineering, and mathematics lesson will not have an effect on student interest/motivation within STEM courses, was only partially rejected. This was because there was a positive effect in two of the classes, *Introduction to Foods, Agriculture, and Natural Resources*; and *Natural Resources*, no effect in the *General Science* class, and while not statistically significant, a negative effect in the *Introduction to Engineering Design* class.

CHAPTER 5. CONCLUSIONS, DISCUSSION, AND RECOMMENDATIONS

5.1 Study Summary

The goal of this thesis was to address the question, does teaching a single lesson, utilizing the interconnected principles of STEM (Science, Technology, Engineering, and Mathematics) in STEM courses, increase student interest and engagement in STEM classes in secondary schools? While conducting the literature review, it was found that there is not enough employees in STEM fields (Denney, 2011), but the larger problem was the lack of students who are prepared for STEM careers (Denney, 2011). There were a few factors related to this, with the biggest being a lack of student interest. This aligned with National Academy of Engineers' goal of increasing student interest and engagement by implementing integrated STEM education (Honey et al., 2014).

Integrated STEM education is a newer idea that attempts to combine content and standards from multiple STEM disciplines into one coherent package. This allows such benefits as real-world application and critical thinking (Honey et al., 2014). Two definitions work well when defining STEM integration. First, the National Academy of Engineers define integration as, "working in the context of complex phenomena or situations on tasks that require students to use knowledge and skills from multiple disciplines" (Honey et al., 2014, p. 52). Laboy-Rush (2007) defines STEM integration as:

> Any program in which there is an explicit assimilation of concepts from more than one discipline. Integrated STEM education programs apply equal attention to the standards and objectives of two or more of the STEM fields – Science, Technology, Engineering and Math. (p.3)

Using the principles of integrated STEM education, *Methods of Integrated STEM Education,* a class of six preservice teachers at Purdue University, spent a semester developing integrated STEM lessons with a focus on learner centered teaching. Preservice teachers worked extensively with professors who were experts in their given STEM field as well as the cooperating teachers from the test site school. At the conclusion of the semester, the preservice teachers were able to implement their lessons in the participating test site school due to the school being very interested in integrated STEM education. This created an excellent opportunity to research possible outcomes from the integrated STEM lessons.

Four STEM classrooms at the test site school were used for this study: *Introduction to Foods, Agriculture*, *and Natural Resources*; *Natural Resources; General Science*; and *Introduction to Engineering Design*. Originally another class, Principles of Engineering, was also to be included in this study because two of the Purdue preservice teachers taught in that class. However, poor response rates from participating students led to insufficient data, which had to be dropped.

In order to gauge student interest/motivation, the Intrinsic Motivation Inventory instrument was chosen. The instrument's items are based on a likert scale from one to seven and originally consisted of seven subsets. The instrument allowed for customization, meaning only the most relevant subsets needed to be used. The subsets perceived competence, effort/importance, value/usefulness, and interest/enjoyment were used because the most closely related to interest and engagement. The excluded subsets were perceived choice, felt pressure/tension, and relatedness. In total, the four included subsets formed a survey of 25 questions with a scoring range of 25-175.

The research design utilized a multiple baseline methodology (A-A-B-A-A replication), with the intention of comparing the treatment to existing levels of student interest/motivation. This was chosen because there were no comparison groups. During the baseline measurements (A), students were surveyed after the normally planned lesson for that day, meaning that the teacher from each class taught as if no research was happening. However, the treatment lesson (B) was taught by the guest Purdue preservice teacher and focused on integrated STEM principles. The participating students responded through an online survey.

The study originally consisted of 69 students, but not all students were present during the treatment lesson. Those absent students were then removed, dropping the number to 49. After all survey data was collected, analyses of overall student scores were conducted for all participating students as a whole. Then, each of the four participating classrooms were analyzed separately due to the different types of content taught in each class. Then, analyses were also run on the subset, interest/enjoyment, due to its more direct relevance to the research question of interest and engagement. To analyze, the mixed model $Y_{IJK}=S_I+C_J+T_K+(CT)_{JK}+ \varepsilon_{IJK}$, visual figure observations, and pairwise comparisons were used to find the most significant changes during the series of surveys (*p* values <.05 considered significant).

Initially after running pairwise comparison, only the *Natural Resources* class encountered a statistically significant increase of interest/motivation from the second baseline to the treatment (p=.05). *Introduction to Foods, Agriculture, and Natural Resources* only came very close with p=.073. *General Science* did not produce anything close to statistical significance, and *Introduction to Engineering Design* produced p=.182, but in the negative direction.

Different results were found when specifically looking at the interest/enjoyment subset. *Introduction to Foods, Agriculture, and Natural Resources* increased significantly between the second baseline and the treatment (p=.027), and *Natural Resources* significantly increased between the second baseline and treatment (p=.042). However, *General Science* and *Introduction to Engineering Design* followed the same trend from the overall analysis.

The overall analysis concluded that there was no difference in interest/motivation when the treatment was compared to the baseline lessons in the overall sample. However, after analysis was run for each individual class, one class showed a significantly positive difference, two showed slightly positive differences, and one showed a negative difference during the treatment lesson.

5.2 Potential Issues with Validity

Although many precautions were taken to avoid threats to validity within this study, such as precise directions for cooperating teachers and lesson development, certain limitations existed that could not be controlled. The following subsections address the encountered issues with validity.

5.2.1 Internal Threats

1. History- The largest issue with history happened in the *General Science* class. Originally there were 24 participating students, but eight of those students were absent on the day of the treatment due to an extracurricular school activity. Those students were still able to complete all of the baseline surveys, but their data was removed because they missed the treatment, reducing the sample size to 16.
2. Mortality- The experimenter could not personally make sure that participating students completed surveys. To remedy this, the cooperating teachers made the surveys part of student grades. For three of the classes, student response rates were consistent, but for the fourth class, *Introduction to Engineering Design*, the teacher did not offer credit. It is not known if the lack of credit was the reason, but regardless, response rates were extremely poor. There were 16 students in the *Introduction to Engineering Design* class, 15 took the first baseline survey, 10 took the

second survey, nine took the treatment survey, five took the third baseline, and only four took the final fourth baseline survey. Then, after removing the participants who did not take the treatment survey, the respective survey response rates were nine, eight, nine, five, and four. These responses did not provide a large sample. This was the same reason for eliminating the Principles of Engineering class from the data set (same cooperating teacher). The class began with an already small sample of seven students, and by the end of the experiment, only one student had taken the final survey.

3. Testing- Creating a research design in this case was difficult due to the lack of a comparison group. The multiple baseline method was used so student growth could be compared to their own previous and post experiences. In theory, this method should work fine, but it cannot account for student participation. The exact same survey was given to students five times within two weeks, which could be repetitive and boring to students. Cooperating teachers had reported to the researcher that students wanted to take different surveys instead of the same one over and over. That however, would not have worked in this study. The repetitive nature may have deterred students from participating or answering with complete honesty, especially during the last two surveys. Students were aware that they were being tested from the beginning of the study.

4. Instrumentation- Four separate classes of different contents were used for this study. Each class had a different teacher and a different set of lessons involved. Although the treatment lesson for each class was an integrated STEM lesson created by a Purdue preservice teacher, the lesson was different for each class.
5. Experimenter- The treatment lessons were delivered by Purdue preservice teaching guests, while the baseline lessons were taught by the students' normal teacher. This may or may not have caused participating students to behave or participate more in the lesson because of the guest teacher.

5.2.2 External Threats

1. Small Sample Size- While the overall sample consisted of 49 students, the samples for each individual class were much less and may not represent STEM classes as a whole.
2. Interaction Effects of Selection and the Independent Variable- Compounding internal threats may have made it difficult to determine if effects were caused by treatment or characteristics of the participating students. Time commitment or possibility of repetitiveness may hinder student decisions.
3. Interaction Effects of Setting and the Independent Variable- This study took place during the end of the semester and the content of the baseline lessons could not be controlled by the researcher.

5.3 Discussion

After this study, a few conclusions could be made. The study set out to address if integrated STEM lessons would have an effect on student interest/motivation in STEM classes. Beginning with an overall analysis of all four of the combined classes, no statistically significant change was found. However, when looking at the figure (*Figure 4.4.3*), it can be visually interpreted that a positive change in interest/motivation did happen during the treatment portion of the study. That being said, all four classes experienced different lessons and should be analyzed separately.

5.3.1 Discussion: Agricultural Science Classes

Both of the agriculture classes, *Natural Resources* and *Introduction to Foods, Agriculture, and Natural Resources*, are included in this section of conclusions because of their similarities. Both classes were taught by the same cooperating teacher, but the treatment lessons were still taught by separate Purdue preservice teachers. Both classes also experienced similar changes in interest/motivation throughout the study. *Introduction to Foods, Agriculture, and Natural Resources* came very close to increasing significantly (p=.073), and *Natural Resources* did increase significantly (p=.05). Then, when looking specifically at the interest/enjoyment subset, *Introduction to Foods, Agriculture, and Natural Resources* increased (p=.027), as well as *Natural Resources* (p=.042).

It can be concluded that integrated STEM lessons did have a positive effect on student interest/motivation in both of these classes. There may be multiple factors relevant to why there was an increase in interest/motivation during the treatment. When referring back to the baseline lessons for each class (sections 3.6.1 and 3.6.2), the content may provide an answer. In both classes, the first two baselines consisted of a non-group activity, and the second two baselines consisted of an E-learning trial day and a test or test review. None of the baselines consisted of any STEM integration, only agricultural content. The average of the baselines were very low (*Introduction to Agriculture, Foods, and Natural Resources*, M=90.45; *Natural Resources*, M=105.06) when compared to the average baselines of *General Science* (M=136.87) and *Introduction to Engineering Design* (M=143.56). This could indicate that the integrated STEM lessons created interest/motivation by adding integration and active learning that the students were not accustomed to, but it cannot be known for certain. Regardless, using multiple STEM standards and a learner-centered approach had a positive effect on interest/motivation when comparing the treatment to the baseline lessons. Lastly, the large effect sizes determined by Cohen's *d* indicate high practical significance (Introduction to Agriculture, Foods, and Natural Resources *d*=2.58, Natural Resources *d*=2.81, both were measured by comparing baseline two to the treatment; see *Table 4.5.1*).

5.3.2 Discussion: General Science

Of the four participating classes, *General Science* showed the least amount of change over time. At no point was there ever any statistically significant increase or decrease in student interest/motivation. Part of this could have been due to the eight absent students on the day of the treatment survey (33% of the class population). When analysis was run with the inclusion of those absent eight students and their baseline scores, the figure shows a bit of a peak during treatment, but it is unclear what kind of change would have happened had they been there during treatment.

One thing worth noting is the overall averages of surveys within this class. From the beginning to end, their averages per survey were 141.25, 142.67, 138.13, 132.92, and 130.67 respectively. Although not the highest, the score for the treatment survey (M= 138.13) is still much higher than both of the treatment scores for *Introduction to Foods, Agriculture, and Natural Resources* (M= 107.81) and *Natural Resources* (M= 127.25). This could mean that *General Science* already employed integrative STEM or active learning methods. (See section 3.6.3 for an overview of the lessons).

When looking at the baseline content from section 3.6.3, it is clear that all of the content focused on DNA, linking all lessons together. Even the guest Purdue preservice teacher put in effort to make sure his content aligned with what was already happening in the class. This could have enabled interest/motivation to flow consistently through all lessons. During the baselines, students watched a movie (applicable to what they were learning and real-world application), led group discussions, and participated in group activities. All of these lessons consisted of real-world application, and learner-centered teaching, both of which were major goals of integrated STEM. Some lessons even contained standards from multiple STEM disciplines. It can be concluded that the integrated STEM lesson neither hindered nor benefitted student interest/motivation, because STEM integration and active learning were already happening. This also violated the initial assumption that no STEM integration was happening during the baseline lessons. Overall, interest/motivation generally maintained high scores within the *General Science* class. Cohen's *d* results indicated a medium to high practical significance when comparing baseline two to the treatment (d=.716; see *Table 4.5.1*).

5.3.3 Discussion: Introduction to Engineering Design

The final class in this discussion, *Introduction to Engineering Design*, showed a decrease in interest/motivation when looking at the figure (*Figure 4.4.4.3*). Just like the General Science class, the averages tell a story (M= 152.34, 147.75, 131.67, 132.4, and 141.75 respectively). The very first survey (also one of the highest response rates, with nine students), had a high score of 152.34 out of 175, then maintained high averages for all of the baselines.

When looking at the lesson overview for this class (section 3.6.4), it is clear that students were in the middle of a hands on project when the treatment lesson happened. This treatment lesson could have interrupted the flow of student interest/motivation when they were already engrossed in the Puzzle Cube project. This project consisted of students individually designing and constructing a simple cube that could only be put together using a complex pattern. Students used graphing, computer modeling, manufacturing, and structural analysis to complete their final product. The initial baseline scores indicate much higher interest/motivation than the other three classes involved. This could be because Introduction to Engineering Design and its developer, Project Lead the Way, already strive for integrated STEM principles (Project Lead the Way, 2014). Also, students may not have found the integrated STEM lesson to be relevant, and relevance is necessary for maintaining interest (Beier & Rittmayer, 2008). The treatment lesson focused on tire traction when driving a vehicle, and these students had most likely not yet driven a car before, as the class was made up of freshmen and sophomores (generally 14 to 15 years old). Cohen's *d* results indicated a high practical significance when comparing baseline two to the treatment (d=1.93; see *Table 4.5.1*).

It can be concluded that, while interest/motivation dropped during the integrated STEM treatment lesson, *Introduction to Engineering Design* had already reached high levels student interest/motivation in STEM, creating a ceiling effect.

5.4 Conclusion

After analyzing the results and conditions of each classroom, two major trends can be noticed. The science and engineering/technology class did not show any improvement or significant change during the treatment, while the agriculture classes did. As stated in the discussion, the science and engineering/technology classes were already experiencing integrated STEM lessons and active learning and earned high scores of interest/motivation during the baseline lessons. This could have been because the school was already working towards an integrated STEM initiative and these two classes had already made more progress than the researcher had anticipated. The agricultural lessons however, were not integrated, did not focus on active learning, and had low scores of interest/motivation during the baseline surveys.

5.4.1 Interest/Motivation from Integrated STEM Lessons

After reflecting on the content from the two agriculture classes, no evidence was presented by the teacher or lessons indicating that STEM integration or active learning were happening. The STEM integrated treatment lesson led to an increase in student interest/motivation showing that STEM integration will increase interest/motivation when no prior STEM integration is happening.

5.4.2 No Difference in Interest/Motivation

The *General Science* class clearly showed no significant change in interest/motivation between any of the surveys. Again, this was believed to have happened because, contrary to the original assumption, all of the lessons already contained STEM integration and active learning.

5.4.3 Consistent Lessons

The final conclusion builds off of the previous one. Like *General Science, Introduction to Engineering Design* did not show a significant difference in interest/motivation between the surveys. It did however, noticeably drop, not significantly, during the treatment lesson. This was due to the nature and timing of the integrated STEM treatment lesson. The class was already engaged in an integrated STEM and active learning experience when the treatment happened. However, the treatment lesson was unrelated to what the students were currently doing which interrupted their progress and attention. This was unlike the *General Science* class where all five lessons, including the treatment, were connected. Therefore, the final conclusion speaks to integrated STEM and teaching in general; lessons must flow and make connections to each other in order to maintain student interest.

5.5 Recommendations

At the conclusion of this research, there was a mix of different results. Through these results, different recommendations can be made for the future of integrated STEM education.

5.5.1 Recommendations for Teachers

Teachers of the STEM fields need to do their part to increase student interest in STEM as students leave high school. Based off of this study, integrated STEM education has shown promise for increasing interest. However, there are many different forms of STEM integration (Honey et al., 2014), some methods may work better or worse for different teachers.

The integrated STEM treatment lessons from this study utilized Learner-Centered Teaching and a mix of standards from at least three STEM areas. Again, research has shown that there is still not yet a standardized way to implement integrated STEM lessons. It is recommended that teachers consider the methods used in this study as well as review the text, *STEM Integration in K-12 Education: Status, Prospects, and an Agenda for Research,* by the National Academy of Engineering (Honey et al., 2014).

Integrated STEM education is still early in development and there is much freedom in how to implement. Creativity will play a key role in future development of integrated STEM education. This research utilized concepts such as learner-centered teaching, real-world applications, and problem-based thinking. None of these concepts are exclusively limited to integrated STEM education and should be used in any classroom. This could lead to better problem solvers and a higher interest in academia in general.

Last, when writing curriculum, content needs to be relevant and up to date. Finding problems or activities that directly relate to students could greatly affect interest (Beier & Rittmayer, 2008). Just like the possible lack of relevance in the integrated STEM lesson used in *Introduction to Engineering Design* during this study, students could completely disengage when they do not care about the problem. Staying current may also show that the teacher has interest in students' lives, building more personal relationships and creating a more beneficial learning environment for all involved.

5.5.2 Recommendations for Future Research

Integrated STEM education is a newer form of learning that is still lacking in the realms of research (Honey et al., 2014). This study made the best of a good opportunity, but overall, the study needed to be stronger. Based on the outcomes of this study, certain recommendations can be made for future research.

1. Replicate this study on a larger scale. The classes used in this study, *Introduction to Foods, Agriculture, and Natural Resources* (n=16 students), *Natural Resources* (n=8 students), *General Science* (n=16 students), and *Introduction to Engineering Design* (n=9 students), were made up of small samples adding up to 49, which was not very powerful. This study was limited to a small rural secondary school and is not generalizable for all STEM classes. Gathering data from larger samples and varying schools would be more informative.
2. If possible, include comparison groups instead of using the multiple baseline method (A-A-B-A-A). The repetitive nature of the many surveys was not ideal for students who grew bored and either quit responding or quit answering honestly. If the multiple baselines are in fact needed, try spreading them out over the course of a semester. This would allow generalizations to be made about overall interest throughout the semester,

as well as relieve students from constant surveys in a short amount of time. If surveys are more spaced out and students accept them as part of the class, it may eliminate the testing effect.

3. Create a standardized integrated STEM lesson format that could be implemented in any STEM class. Part of the problem with this study was variation of treatment in each of the participating classes. Creating a standard lesson applicable to any STEM class could help gauge the effectiveness of different treatments.
4. Further investigate Project Lead the Way (PLTW) classes in order to see what practices are being used to increase interest/motivation. In this study, the PLTW Introduction to Engineering Design class had higher levels of interest/motivation in the baselines than any other class did during the treatment.
5. Eliminate guest teachers from the treatment. Students may or may not have been better behaved and attentive due to having a guest teacher. Have the STEM classroom teachers deliver treatment lessons themselves in order to remove experimenter effect.
6. Collect as much information as possible on the baseline lessons. This will help make clear what kind of lessons are affecting interest and will allow better comparison between baseline lessons and treatments. This study was only able to collect a brief overview of each baseline lesson (section 3.6). Teacher reflections of each lesson would also provide insight on student and lesson proceedings.

7. The National Academy of Engineers indicated four other areas for further integrated STEM research: STEM literacy, 21st century competencies, STEM workforce readiness, and the ability to make connections among STEM disciplines (Honey et al., 2014). Identify if any of these other goals can be studied at the same time and how to do so.

5.6 Chapter Five Summary

In conclusion, this study set out to answer the research question: Does teaching a single lesson, utilizing the interconnected principles of STEM in STEM courses, increase overall student interest and engagement in STEM classes in secondary schools? The literature review established a need for student interest in STEM to help fill future STEM careers. Integrated STEM lessons were a viable option for increasing interest, but existing research on the matter was limited.

Integrated STEM lessons were applied at a test site school using a multiple baseline framework and evaluated responses with a variation of the Intrinsic Motivation Inventory (IMI). According to the results, two of the classes, *Natural Resources*, and *Introduction to Agriculture, Foods, and Natural Resources*, showed improved interest/motivation when exposed to an integrated STEM lesson. Two other classes, *General Science*, and *Introduction to Engineering Design*, did not show improvement, but maintained high scores on the IMI throughout the study and may have represented a ceiling effect.

At the end of data collection and analysis, it was concluded that integrated STEM lessons show potential for increasing student interest/motivation in STEM in certain contexts, depending on what was happening in each classroom. Recommendations were then made to build stronger studies in the future and better control potential threats to validity. Integrated STEM education needs to be further investigated, manipulated, and implemented to better impact future students, STEM education, and future STEM careers.

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APPENDICES

Appendix A: Surveys

Reflection on the Lesson

Name________________
Date________________
Teacher________________
Class Period________________

For each of the following statements, please indicate how true it is for you, using the following scale:

Not True at all			Somewhat True			Very True
1	2	3	4	5	6	7

After working at this lesson for a while, I felt pretty competent.	1	2	3	4	5	6	7
I am satisfied with my performance on this lesson.	1	2	3	4	5	6	7
I believe doing this lesson could be beneficial to me.	1	2	3	4	5	6	7
I believe this lesson could be some value to me.	1	2	3	4	5	6	7
I didn't put much energy into this.	1	2	3	4	5	6	7
I didn't try very hard to do well at this lesson.	1	2	3	4	5	6	7
I enjoyed doing this lesson very much.	1	2	3	4	5	6	7
I put a lot of effort into this.	1	2	3	4	5	6	7
I think doing this lesson could help me.	1	2	3	4	5	6	7
I think I am pretty good at this lesson.	1	2	3	4	5	6	7
I think I did pretty well at this lesson, compared to other students.	1	2	3	4	5	6	7
I think that doing this lesson is useful.	1	2	3	4	5	6	7
I think this is an important lesson.	1	2	3	4	5	6	7
I thought this lesson was quite enjoyable.	1	2	3	4	5	6	7
I thought this was a boring lesson.	1	2	3	4	5	6	7
I tried very hard on this lesson.	1	2	3	4	5	6	7
I was pretty skilled at this lesson.	1	2	3	4	5	6	7
I would be willing to do this lesson again because it has some value to me.	1	2	3	4	5	6	7
I would describe this lesson as very interesting.	1	2	3	4	5	6	7
It was important to me to do well at this lesson.	1	2	3	4	5	6	7
This lesson did not hold my attention at all.	1	2	3	4	5	6	7
This lesson was fun to do.	1	2	3	4	5	6	7
This was a lesson that I couldn't do very well.	1	2	3	4	5	6	7
While I was doing this lesson, I was thinking about how much I enjoyed it.	1	2	3	4	5	6	7
I think this is important.	1	2	3	4	5	6	7

Frontier Jr/Sr High School: Reflection on the Lesson

For each of the following statements, please indicate how true it is for you, using the 1-7 scale. A "1" means that the statement is not at all true to you, and a "7" means that it is true for you. Please answer honestly, your teacher will not see your response.

* Required

Your Name *

Your Teacher's Name *

Class Period *

Today's Date *

Month | Day | 2014

Please answer each statement honestly, your responses will remain anonymous. *

Survey Continued

Please answer each statement honestly, your responses will remain anonymous. *

	Not True at all 1	2	3	Somewhat True 4	5	6	Very True 7
After working at this lesson for a while, I felt pretty competent.	○	○	○	○	○	○	○
I am satisfied with my performance on this lesson.	○	○	○	○	○	○	○
I believe this lesson could be some value to me.	○	○	○	○	○	○	○
I did not put much energy into this.	○	○	○	○	○	○	○
I did not try very hard to do well at this lesson.	○	○	○	○	○	○	○
I enjoyed doing this lesson very much.	○	○	○	○	○	○	○
I put a lot of effort into this.	○	○	○	○	○	○	○
I think doing this lesson could help me.	○	○	○	○	○	○	○
I think I am pretty good at this lesson.	○	○	○	○	○	○	○
I think I did pretty well at this lesson, compared to other students.	○	○	○	○	○	○	○
I think that doing this lesson is useful.	○	○	○	○	○	○	○
I think this is an important lesson.	○	○	○	○	○	○	○
I thought this lesson was quite enjoyable.	○	○	○	○	○	○	○
I thought this was a boring lesson.	○	○	○	○	○	○	○
I tried very hard at this lesson.	○	○	○	○	○	○	○
I was pretty skilled at this	○	○	○	○	○	○	○

Survey Continued

I thought this was a boring lesson.							
I tried very hard at this lesson.							
I was pretty skilled at this lesson.							
I would be willing to do this lesson again because it has some value to me.							
I would describe this lesson as very interesting.							
It was important to me to do well at this lesson.							
This lesson did not hold my attention at all.							
This lesson was fun to do.							
This was a lesson that I could not do very well.							
While I was doing this lesson, I was thinking about how much I enjoyed it.							
I think this is important.							
I believe doing this lesson could be beneficial to me.							

Submit

Never submit passwords through Google Forms.

Appendix B: Institutional Review Board

PURDUE
UNIVERSITY

HUMAN RESEARCH PROTECTION PROGRAM
INSTITUTIONAL REVIEW BOARDS

To:	NATHAN MENTZER YONG
From:	JEANNIE DICLEMENTI, Chair Social Science IRB
Date:	11/21/2014
Committee Action:	**Exemption Granted**
IRB Action Date:	11/21/2014
IRB Protocol #:	1411015461
Study Title:	Student Interest and Engagement after STEM integration

The Institutional Review Board (IRB) has reviewed the above-referenced study application and has determined that it meets the criteria for exemption under 45 CFR 46.101(b)(1) .

If you wish to make changes to this study, please refer to our guidance "**Minor Changes Not Requiring Review**" located on our website at http://www.irb.purdue.edu/policies.php. For changes requiring IRB review, please submit an **Amendment to Approved Study** form or **Personnel Amendment to Study** form, whichever is applicable, located on the forms page of our website www.irb.purdue.edu/forms.php. Please contact our office if you have any questions.

Below is a list of best practices that we request you use when conducting your research. The list contains both general items as well as those specific to the different exemption categories.

General

- To recruit from Purdue University classrooms, the instructor and all others associated with conduct of the course (e.g., teaching assistants) must not be present during announcement of the research opportunity or any recruitment activity. This may be accomplished by announcing, in advance, that class will either start later than usual or end earlier than usual so this activity may occur. It should be emphasized that attendance at the announcement and recruitment are voluntary and the student's attendance and enrollment decision will not be shared with those administering the course.
- If students earn extra credit towards their course grade through participation in a research project conducted by someone other than the course instructor(s), such as in the example above, the students participation should only be shared with the course instructor(s) at the end of the semester. Additionally, instructors who allow extra credit to be earned through participation in research must also provide an opportunity for students to earn comparable extra credit through a non-research activity requiring an amount of time and effort comparable to the research option.
- When conducting human subjects research at a non-Purdue college/university, investigators are urged to contact that institution's IRB to determine requirements for conducting research at that institution.
- When human subjects research will be conducted in schools or places of business, investigators must obtain written permission from an appropriate authority within the organization. If the written permission was not submitted with the study application at the time of IRB review (e.g., the school would not issue the letter without

IRB Continued

proof of IRB approval, etc.), the investigator must submit the written permission to the IRB prior to engaging in the research activities (e.g., recruitment, study procedures, etc.). This is an institutional requirement.

Category 1

- When human subjects research will be conducted in schools or places of business, investigators must obtain written permission from an appropriate authority within the organization. If the written permission was not submitted with the study application at the time of IRB review (e.g., the school would not issue the letter without proof of IRB approval, etc.), the investigator must submit the written permission to the IRB prior to engaging in the research activities (e.g., recruitment, study procedures, etc.). This is an institutional requirement.

Categories 2 and 3

- Surveys and questionnaires should indicate
  - only participants 18 years of age and over are eligible to participate in the research; and
  - that participation is voluntary; and
  - that any questions may be skipped; and
  - include the investigator's name and contact information.
- Investigators should explain to participants the amount of time required to participate. Additionally, they should explain to participants how confidentiality will be maintained or if it will not be maintained.
- When conducting focus group research, investigators cannot guarantee that all participants in the focus group will maintain the confidentiality of other group participants. The investigator should make participants aware of this potential for breach of confidentiality.
- When human subjects research will be conducted in schools or places of business, investigators must obtain written permission from an appropriate authority within the organization. If the written permission was not submitted with the study application at the time of IRB review (e.g., the school would not issue the letter without proof of IRB approval, etc.), the investigator must submit the written permission to the IRB prior to engaging in the research activities (e.g., recruitment, study procedures, etc.). This is an institutional requirement.

Category 6

- Surveys and data collection instruments should note that participation is voluntary.
- Surveys and data collection instruments should note that participants may skip any questions.
- When taste testing foods which are highly allergenic (e.g., peanuts, milk, etc.) investigators should disclose the possibility of a reaction to potential subjects.

Appendix C: Integrated STEM Lesson Plans

Integrated STEM Lesson: Extreme Makeover School Edition

Integrated STEM Education Lesson Plan

Topic: Extreme Makeover- School Edition **Course**: Intro. To Agriculture **Grade Level**: 8-12 (mostly 8)

Learning Objectives:
1. Students will be able to apply the engineering design process.
2. Students will be able to design a wildlife habitat.
3. Students will be able to describe human impact on ecosystems.

Situating the Content:
1. What was previously taught? Animal nutrition. wildlife population management. growth. development. reproduction of animals and wildlife.

2. What will be taught next? Aquatic animals and habitats

3. Why this content is important to learn? Big picture: Everything is connected in the ecosystem; the ways in which humans impact their surroundings will in turn affect humans. The engineering design process can be used to address problems and create solutions.

4. What is/are the I-STEM goal? The goal is to increase student engagement and create a real and relevant situation for students by incorporating the STEM subjects.

5. What is the relationship between STEM connections (Concepts, Practices or Both)? The relationship between the STEM connections in this activity is that content from science and agriculture will be applied through engineering design practices.

6. How does the addition of a supporting STEM field improve student:

   a. Understanding of the anchor discipline?
   The supporting disciplines allow the students to explore a topic from the anchor discipline in a much more in-depth manner. They make the learning more real and relevant.

   b. Understanding of the relationships between fields?
   The addition of supporting STEM fields helps show that in the real world agriculture involves all of the STEM disciplines, therefore utilizing skills and building knowledge and familiarity will Science, Technology, Engineering, and Math is beneficial for students success if they plan to pursue careers in agriculture.

Learning Standards:

*Note: Not all standards will be covered in depth. Some will just be briefly touched on, as information that is useful to know.

Anchor domain: Agriculture

IN INTRO TO AGRICULTURE, FOOD, & NATURAL RESOURCES STANDARDS
IAFNR-2.1 Acquire and demonstrate communication skills such as writing, public speaking, and listening while refining oral, written, and verbal skills.

Connector domain(s): Science, Technology, Math

IN 8TH GRADE SCIENCE STANDARDS
8.2.6 Identify, explain and discuss some effects human activities (e.g., air, soil, light, and noise and water pollution) have on the biosphere.
8.2.8 Explain that human activities have drastically changed the environment and have affected the capacity of the environment to support native species. Explain current efforts to reduce and eliminate these impacts and encourage sustainability.
8.3.1 Explain that reproduction is essential for the continuation of every species and is the mechanism by which all organisms transmit genetic information.

STANDARDS FOR TECHNOLOGICAL LITERACY
15.I. Artificial ecosystems are human made complexes that replicate some aspects of the natural environment.
15.N. The engineering design and management of agricultural systems require knowledge of artificial ecosystems and the effects of technological development on flora and fauna.

IN 7TH GRADE MATH STANDARDS
7.GM.3: Solve real-world and other mathematical problems involving scale drawings of geometric figures, including computing actual lengths and areas from a scale drawing. Create a scale drawing by using proportional reasoning.

Assessment:
Day 1
Formative: Real-time feedback will be provided.
Summative: The final group design will be assessed based on the included rubric.
Day 2
Student understanding of the concepts will be assessed during group discussion.
Students will also be asked to write about what they learned during the experience.

DAY 1

Time	Teaching Method	Instructions & Learning Activity	Materials & Resources	Connections Content & Practices
3min	Introduction	Introduction regarding me, why I am there, and that we will be focusing on an integrated STEM activity. Ask students, "What is integrated STEM?" in order to gauge understanding, and explicitly recognize integration.	Computer, projector, PowerPoint	Integrated STEM as a whole
1min	Video	https://www.youtube.com/watch?v=g4WbnRylruc Video about a school which created a wildlife habitat. Show from beginning- 55 second mark. Distribute design brief and rubric during this time.	Internet access, computer, projector, speakers, design brief, rubric	Video= Multiple Representations
3min	Getting into groups	Students get into groups of 3-4. Frontier teacher provides assistance in organizing groups.		Social Learning
3-5min	Independent reading	Give students 3-5 minutes to read over the design brief.		Design Brief= Engineering, Real world problem
5min	Class discussion	Ask the class questions including: • What is the problem/challenge? • Who is the user? • What are the constraints?		Engineering Design
3min	Video	http://www.ted.com/talks/eric_sanderson_pictures_new_york_before_the_city?language=en#t-646291 TED Talk video about habitat. Show from 8:15 to 11:00 minute marker. Distribute specific wildlife species habitat requirements to groups during this time. 3 species: eastern cottontail rabbits, butterflies, songbirds. Ensure that there is at least one group assigned to each species, and then continue assigning groups so that proportions are equal.	Internet access, computer, projector, speakers, habitat fact sheets for rabbit, butterfly, and songbird	Video= Multiple Representations, Science

3-5 min	Group discussions	Give students 3-5 minutes to look over habitat factsheets for their species and discuss the questions below. Inform them that they will be sharing their answers with the class after their group discussions, in order to keep them focused on the questions. • What are the components of habitat for your specific species you are required to include your design? • Why do you have to include these components in your landscape design? Why is it beneficial for your habitat species?	Computer, projector, PowerPoint	Social Learning, Real world problems, Science
5min	Class discussion	Have a spokesperson from each group share with the class which animal species they were assigned and share their answers to the questions above with the rest of the class. Hand out grid paper while this is taking place.	Grid paper	Grid paper= tool or object
3min	Direction	Share with students that next they will be working in groups to create their designs. Remind students to refer to their rubric for guidance. Remind them to incorporate the needs of their assigned wildlife species. Tell them that they can refer to the aerial photo and street view photo to help them. Emphasize that the design needs to be created to scale. Ask them if they know what this means and to share with the class how they can do this? Mention that they can either create one group design from the beginning, or create individual designs first, and then take elements of those to create a final group design.		Designing to scale= math

10-15min	Working in groups	Then have students work in groups to create their designs. While students are working in groups, circulate room and ask questions regarding elements of their designs, how they are incorporating habitat needs, and how they are meeting the criteria of the rubric.		Social learning, embodied experience= acting as the designer, incorporating principles of engineering, concepts of science, and utilizing math skills
5-8min	Sharing with the class	Allow representatives from each group to share and explain their design to the rest of the class. Ask questions to help students make connections between similar wildlife species habitat needs.		
3-8min	Class discussion	Ask guiding questions to encourage students to think about what the area outside Frontier used to look like, how humans have impacted it, how human impacts have affected wildlife, how that has in turn affected humans. Ask questions regarding living and non-living components of designs and why they are both necessary. Ask questions regarding ecosystems, and how these man-made designed ecosystems mimic natural ecosystems.		Science, discussing history of school & human impact= social & cultural features
1min	Conclusion	Thank students for their cooperation.		

DAY 2

Time	Teaching Method	Instructions & Learning Activity	Materials & Resources	Connections Content & Practices
2min	Teacher led discussion	Review of the last class period.		
5min	Independent work-time	Students work independently to answer the four questions on the "Exploring Wildlife Habitat" worksheet.	Exploring Wildlife Habitat Worksheet	Reflection
5min	Class discussion	Students are asked to share their responses to the questions on the worksheet with the rest of the class.		Shared learning experience
30min	Hands-on activity	Students go outside the school, and use their scaled drawings to lay out their design using tape measurers, string, and stakes. This helps students visualize what their designs would look like once implemented, therefore allowing them to make re-designs if elements seem out of proportion, out of place, etc. This also helps students gain insight regarding what it means to transfer a scaled design on paper into a real life context, and makes the math concept of scale more realistic and visual.	Tape measurers, string, stakes, student created landscape designs, clipboards	Authentic activity using math concept of scale, using plan created using engineering design process and incorporating scientific concepts
2	Review & Closure	Review- Brief summary Preview- Preview of next class What is due? Exploring Wildlife Habitat to be turned in before the end of class.		

Integrated STEM Lesson: Reduction of Bass Population

Reduction of Bass Population: A Case Study

Topic: Animal Wildlife **Course**: Natural Resources
Grade Level: 9
School Name: xxxxx
Teachers: Mrs. xxxxx

Learning Objectives:

1. Identify characteristics of a healthy wildlife habitat (Indiana Academic Standards for Natural Resources, NR-7.2)
2. Make inferences from data to predict results (Indiana Academic Standards for Mathematics (Standard 1, Computation and Estimation) and for Algebra II (AII.DSP.1)
3. Formulate ideas to design a management plan (Engineering Thinking, Framework for Quality K-12 Engineering Ed).

Situating the Content:

1. **What was previously taught?** Core Standard 7. NR-7.1. Explore Wildlife Species
2. **What will be taught next?** Core Standard 8. Animal Wildlife Management
3. **Why this content is important to learn?**

   Natural Resources Content: By learning this content, students will be able to apply natural resources concepts to formulate a management plan for protecting wildlife (Core Standard 7, Indiana Academic Standards for Natural Resources, 9th grade).

4. **What is/are the I-STEM goal(s) [At minimum must include student learning]?**
   Integration of mathematics content: By using a visual representation (data table), students will be able to predict results and infer possible solutions for the case of study (Standard 1, Computation and Estimation, and Standard DSP.1 in Algebra II, Indiana Academic Standards for Mathematics, 9th grade)

   Integration of Engineering content: By judging information students will be able to make decision and formulate ideas for designing a management plan which lead to informed citizenry (Engineering Thinking, Framework for Quality K-12 Engineering Ed).

5. **What is the relationship between STEM connections (Concepts, Practices or Both)?**

In this case of study, students are exposed to a real problem (reduction of bass population) in a authentic context (Lake xxx). Their task is analyzing data collected by a group of local researchers and making inferences from data and information presented in the case regarding the possible causes of the reduction of bass population in Lake Freeman (predators, human intervention during the fish spawning season, habitat characteristics). As a product, students formulate ideas to design a management plan to protect bass population in Lake xxx as it was required by the xxx and xxx Lakes Environmental Conservation Corp. (SFLECC) (client in the engineering process). An adequate management plan provides ecological protection but also economic and sociological benefits for enjoyment of the local community and tourists.

6. How does the addition of a supporting STEM field improve student's understanding of the anchor discipline?

The anchor discipline is natural resources. Instead of giving them the definition of habitat and the list of characteristics a healthy habit needs to have for protecting wildlife, I am using data obtained by local researchers from a context familiar to them (xxx Lake which is located near xxx, the town where the school is situated, in xxx county).

According to the Indiana's Science, Technology, Engineering, and Mathematics (STEM) Initiative Plan, schools that support the learning needs of students connect instruction to real-world problems (p. 10). Because of that, I am focusing on Largemouth Bass (*Micropterus salmoides*) which is abundant in xxx Lake and is exploited sport fish.

7. How does the addition of a supporting STEM field improve student's understanding of the relationships between fields?

I am giving them a real-world problem to facilitate their understanding of a healthy habitat for the fish. Incorporating an additional challenge such as figuring out why bass population is declining (by using a visual representation like a data table) might help them to make connections with algebraic skills such as making inferences from data. Student's ability to judge the information and data presented in the case of the study is part of the process of decision making defined as engineering thinking skills.

8. Learning Standards: Indiana Academic Standards for Natural Resources, 9th grade.

a) **Anchor Domain**: Animal Wildlife (Natural Resources)

- **Core Standard 7:** Students apply knowledge of natural resources to formulate a management plan for protecting wildlife. Standards NR-7.1 Explore wildlife species. NR-7.2 Define characteristics of a healthy wildlife habitat. NR-7.3 Identify methods of wildlife habitat improvement Domain.

b) **Connector domain(s):**

- Indiana Academic Standards for Mathematics, 9th grade.

Standard 1: Use estimation to predict results and to decide if answers are reasonable. Use rations, proportions, and percents to solve problems.

Standard DSP.1 in Algebra II: Make inferences and justify conclusions from sample surveys, experiments, and observational studies.

- Engineering Thinking, Framework for Quality K-12 Engineering Ed.

Assessment: Students end the lesson with an reflection explaining what they did, what they found and how ey did the experience.

ferences:

diana's Science, Technology, Engineering, and Mathematics (STEM) Initiative Plan (2014). Retrieved from: http://www.doe.in.gov/sites/default/files/ccr/indiana-framework-stem-educationv2.pdf

diana Academic Standards for Natural Resources (2014). Retrieved from: p://www.doe.in.gov/sites/default/files/standards/cte-agriculture/cf-ag-naturalresources_7-8-14.pdf

Time	Teaching Method	Instructions & Learning Activity	Materials Resources	Connections Content & Practices
	Day 1: Lesson content	• Students read the case study and watch the two short videos included there • Students read the article published in a local newspaper (Carroll County Comet) about Largemouth Bass in Lake Freeman. The article can be found in the following link: http://www.carrollcountycomet.com/news/2011-10-19/Local_News/SFLECC_placing_game_fish_habitat_bundles_in_Lake_F.html>http://www.carrollcountycomet.com/news/2011-10-19/Local_News/SFLECC_placing_game_fish_habitat_bundles_in_Lake_F.html • Students read the grading rubric	Case study, newspaper article & rubric	
	Day 2: Lesson activity (Cecilia)	• Students work in the handout	Handout	
5 mins	Class introduction & engagement	• Introduction to the problem to be solved What variables could have an impact on the Largemouth Bass population? Work with your team and formulate a management plan for increasing the Largemouth Bass population in Lake xxx • Brief summary of the case study (whole class)	Case study, newspaper article & rubric	Natural resources content: Habitat & management plan
10 mins	Case study: Team discussion & collaboration (Habitat content)	• **Instruction**: Work with your team to identify the components of a healthy habitat presented in Lake xxx • **Activities:** Complete Table 1, and answer the following question: Does xxx Lake provide a healthy habitat for Largemouth Bass? Why? Why not?	Handout: Table 1	Content: healthy wildlife habitat (NR-7.2)

10 mins	Case study cont': Team discussion & collaboration (Calculations)	• **Instruction**: Work with your team to estimate the effect of fishing on the Largemouth Bass population • **Activities:** Answer the following question: How many Largemouth Bass could be lost due to fishing in one day and during the spawning season (approx. 30 days)? Consider the following scenario. Use data in Table 2 • **Scenario:** Suppose that <u>20 anglers per day</u> go for fishing to Lake Freeman. Each one of them catch in average <u>4 male fish per hour</u>. They fish for <u>3 hours</u>	Handout: Scenario & data in Table 2	Content: mathematical skills and representations (PS.4). Predict results. make inferences from data to justify conclusion (Algebra II-AII.DSP.1)
10 mins	Case study cont': Team discussion & collaboration (Management Plan)	• **Instruction:** Work with your team to formulate a management plan for increasing the Largemouth Bass population in Lake xxx • **Activities:** Complete Table 3. Explain <u>how</u> the variables impact on the Largemouth Bass population in Lake xxx. Indicate actions to increase the population of Largemouth Bass in Lake xxx	Handout: Table 3	Content: Engineering Thinking, Framework for Quality K-12 Engineering Ed
5 mins	Review & Closure (Class discussion and conclusion)	• Discussions of the two questions leading the case study What variables could have an impact on the Largemouth Bass population? Work with your team and formulate a management plan for increasing the Largemouth Bass population in Lake xxx		

Integrated STEM Lesson: DNA and Society

Integrated STEM Education Lesson Plan

Topic: Strawberry DNA Extraction **Course**: Life Science **Grade Level**: 8 (Indiana Standards: 8, NGSS: 9-12)

Learning Objectives: Part 1
1. Construct explanations, via research, describing how knowledge from DNA affects society.
2. Recognize how the ability to extract DNA affects society.

Learning Objectives: Part 2
1. Learn how to extract DNA from strawberries.
2. Observe what DNA looks like to the naked eye.

Learning Objectives: Part 3
1. Compare proportions to estimate the amount of DNA in other biological systems.
2. Recognize how the ability to extract DNA affects society.

Situating the Content:
1. What was previously taught? These are the topics scheduled to be addressed before the final micro teach activity.
   Indiana Standards 3 Life Sciences
   (http://www.doe.in.gov/sites/default/files/standards/science/2010-Science-Grade08.pdf)

8.3.1	Explain that reproduction is essential for the continuation of every species and is the mechanism by which all organisms transmit genetic information.
8.3.2	Compare and contrast the transmission of genetic information in sexual and asexual reproduction.
8.3.3	Explain that genetic information is transmitted from parents to offspring mostly by chromosomes.
8.3.4	Understand the relationship between deoxyribonucleic acid (DNA), genes and chromosomes.
8.3.5	Identify and describe the difference between inherited traits and the physical and behavioral traits that are acquired or learned.
8.3.6	Observe anatomical structures of a variety of organisms and describe their similarities and differences. Use the data collected to organize the organisms into groups and predict their relatedness.
8.3.7	Recognize and explain that small genetic differences between parents and offspring can accumulate in successive generations so that descendants may be different from their ancestors.

2. What will be taught next? These are the topics scheduled to be addressed around the time of the final micro teach activity.

8.3.8	Examine traits of individuals within a population of organisms that may give them an advantage in survival and reproduction in given environments or when the environments change.
8.3.9	Describe the effect of environmental changes on populations of organisms when their adaptive characteristics put them at a disadvantage for survival. Describe how extinction of a species can ultimately result from a disadvantage.
8.3.1	Recognize and describe how new varieties of organisms have come about from selective breeding.

3. Why this content is important to learn?

Science Content: This lesson will call back to standard 8.3.3. The purpose is to make the discussion of DNA a tangible thing. By allowing the extraction of the DNA students are able to observe it directly instead of relying on textbook images to simply tell the student it exists.

Math Content: Basic data analysis is a part of the math standards for 8^{th} graders in Indiana. The extraction process gives a context to why before and after data is needed (i.e the activity will mathematize the extraction process).

Technology Content: Having access to DNA is useful because people have developed technology to probe and analyze it. Discussion of how such technology affects members in society provides a context to the science content.

Technology Tool Use: Technology can be used to assist in the data analysis. Students should be aware of how to manipulate and interpret data presented in age appropriate software.

4. What is/are the I-STEM goal(s) [At minimum must include student learning]?

Math Goals: As indicated in part 3 the math content is given context by science content. We plan to carry out an extraction process but how do we quantify what is being done? To answer this make the students aware of mathematical tools that allow analysis. Specific topics, such as data analysis via scatter plots, can be picked from the Indiana math standards. [*Note, this is a limited view of math integration since it ultimately uses math as a tool instead of the broader view of math as a process for understanding phenomenon. However, since this view is consistent with that expressed by the teacher further expansions on this topic will be left to following iterations of this lesson* plan.]

Technology Goals: As indicated in part 3 the science content is given context by the main technology content. The technology standard focuses on how technology affects society. In this case that is a discussion of what society can do, for good or bad, with DNA. The activity then allows students to see how easy it can be to extract DNA and the relative amounts that can be acquired.

5. What is the relationship between STEM connections (Concepts, Practices or Both)?

NGSS Practices of Scientist and Engineers: Numbered in order of appearance in the standards.

4. Analyzing and interpreting data.
   Students will be obtaining data (i.e. measures of the amount of DNA) from the extraction process. The description of what the y-intercept represent in the data is one interpretation of the data that students need to make.
5. Using mathematics and computational thinking.
   Students will utilize data analysis techniques on the data described above. Another view of this is that students will mathematize the extraction process. That is they have a process that produces a certain amount of material from strawberries. Can they transfer this concept to predict what the yield would be from other, similar, experiments?
8. Obtaining, evaluating, and communicating information
   Students will need to evaluate the experimental data but will also need to evaluate and communicate how the science content and data affect their view of the issue of technology and society.

NGSS CrossCutting Concepts: Numbered in order of appearance in the standards.

3. Scale, proportion, and quantity
   Students will be making measurements and comparing between values to make estimations. The students understanding of the accuracy of results here ties to the discussion of error in measurement that is part of students understanding of the scatter plots.
4. System and system models.
   The activity covers the model of DNA (i.e. a single double helix) that students would have seen in lecture, up through the system of DNA (i.e. the mass extracted). A mass of DNA that is extracted is a model system with boundaries (i.e. how does the extracted mass compare with a single strand) that can be expressed by students in this grade band. (NGSS, Appendix F, Pg. 6)
6. Structure and Function.
   This concept is relevant for the domain specific knowledge about how DNA works. This knowledge will be most relevant in the first portion of this activity where students are researching the topic.

6. How does the addition of a supporting STEM field improve student understanding:

   a. Understanding of the anchor discipline?
      Math: As indicated previously, math is brought into this problem as a means of mathematizing the results of the experiment (i.e. to quantify the extracted material). With the material quantified, it is possible to ask new questions based on observations. In this way math informs the science practices.
      Technology: As indicated previously, technology provides context for the science content. An activity where students can simply extract and observe DNA may be interesting, while it is happening, but if a reason is not given for the extraction (and measurements) then the activity is unlikely to engage students in the long run. Ideas of the application and consequence of technology make the science content relevant to the student.

   b. Understanding of the relationships between fields?
      Technology gives context to the science content. Science informs the process of the activity. The process of the activity gives context to the math content. The results of the math will inform how much DNA can be extracted. Here we loop back to technology. With the yield of the extraction process quantified, students can discuss if the results give them any concern based on the discussion of Technology and Society.

Learning Standards:

1. Anchor domain: **Science**

   Indiana Standards 3 Life Sciences:
   8.3.4 Understand the relationship between deoxyribonucleic acid (DNA), genes and chromosomes.

2. Connector domain(s): **Math and Technology**

   Indiana Process Standards for Mathematics: PS.4: Model with Mathematics

   Standards for Technology:
   Standard 4: The Cultural, Social, Economic and Political Effects of Technology
   (http://www.iteaconnect.org/TAA/PDFs/xstnd.pdf)

Assessment:

Formative Assessment:

Students will be engaged in group class discussions of the nature of DNA and impact of DNA on society. These conversations can be monitored for participation and strength of ideas (i.e. supporting evidence, etc.).

As students go through the extraction and measurement parts of the activity they will be collecting data and making observations. The students' work on this can be checked as the students progress through the activity.

Summative Assessment:

Students' final data analysis including a ratio and a prediction about the amount of DNA that might be in a human. This would include any final observations of the experiment.

In class report: A short essay on the on the students perspective of science, technology, and the observations and extraction of DNA in the activity. Importance will be assigned to strength of any verbal arguments.

Period 6: Class Time 1.31 – 2.18 (47 Minutes)

Time	Teaching Method	Instructions & Learning Activity	Materials & Resources	Connections Content & Practices
		Begin Day 1		
5 min	Class Discussion	Personal Introductions and a short description of the full unit activity.	---	---
35 min	Student-Centered Inquiry (PBL)	**Activity:** Student are organized into groups of 3 and put into the role of Investigators who have been given the task of preparing a report for a group of employees who are concerned about the possibility of a company collecting their DNA. Students will have access to a list of organized links (i.e. each link will have a small description highlighting its content) which they will use to address the following 3 questions. 1) What can a company learn about me if they have my DNA? 2) How am I leaving DNA behind? 3) How might the company be getting my DNA?	Worksheet 1: Investigative Report Chromebook Internet Access Document listing approved links.	**Science Content:** DNA, Genetics, Traits caused by Genes. **Technology:** Use of technology in the class and discussion of technology that exist. **Engineering*:** The design process of producing an item (in this case a report) for a client. *This inclusion of engineering is minor and is associated with NGSS Practice 8.
5 min	Class Discussion	**Preview:** Students will be prompted with the question, "How much DNA do you think you have in you?" After noting down the guesses the different students will be left with the question, "How might we try to determine the amount of DNA in a person?"		
	Closure	**What is due?**. At the end of class each group will submit their investigative report.	Worksheet 1: Investigative Report	**Homework:** Verbal and Critical Thinking
		End Day 1		
		Begin Day 2		

5 min	Class Discussion	**Ask students**: Students are given a one page handout that prompts the following question "How could we estimate the amount of DNA in a person if we know the amount of DNA in Strawberry." After the students have read the page engage them in a discussion.		**Math:** Measurement and Ratios
35 min	Activity	**Introduce**: Explain the DNA extraction process to the students. Students will be carrying out the process of extracting the DNA. *This takes the entire period.* The DNA from each group is collected so that it can be compared with the mass of all the strawberries used in the experiment.	Worksheet 2: Activity See extraction procedure worksheet for full list of supplies	**Science:** Process Skills
5 min	Class Discussion	**Preview:** Students are again prompted to think about how to estimate the amount of DNA in a person and are told that data analysis will be carried out the following day.		
	Closure	**What is due?**. For homework the student will write down their observations for the experiment.	Worksheet 2: Observations	**Homework:** Verbal and Critical Thinking
		End Day 2		
		Begin Day 3		
2 min	Class Discussion	**Discussion**: Students are reminded of the previous day's activities and given the numbers (mass of DNA and Strawberries) to work on their data analysis.		
15 min	Activity	**Main Activity:** Students complete their data analysis as a group.	Worksheet 3: Data Analysis	**Math:** Ratios, Proportions

5 min	Lecture:	Once all groups are done, go over the steps involving ratios and proportions to make sure all of the students understand the process. [The mass of DNA in a person is calculated in grams and pounds. It may be useful to compare the amount to some items the students may be failure with. (e.g. a half pound of DNA is two quarter pound hamburger patties.)]		
10 min	Activity	**Activity:** Student will write a one paragraph final report to express their thoughts on the science and technology concepts that have the student has been exposed to during this lesson.	Chromebook/ Google Documents Internet Access	**Report:** Verbal and Critical Thinking
5 min	Class Discussion:	**Review:** The instructor will lead a short class discussion give a summary reminding the students of the content of each of the three days of the lesson and tying that content together.		
	Closure	**What is due?** At the end of class the students will submit their data analysis and final report.		

References: Strawberry DNA Extraction
[*] http://ucbiotech.org/resources/display/files/dna_extraction_from_strawberrie.pdf
[**] http://beam.ucla.edu/sites/default/files/docs/DNA_Extraction.pdf

References: Software
Illuminations: Resources for Teaching Math
[http://illuminations.nctm.org/Activity.aspx?id=4186]

References: NGSS
http://www.nextgenscience.org/sites/ngss/files/Appendix%20F%20%20Science%20and%20Engineering%20Practices%20in%20the%20NGSS%20-%20FINAL%20060513.pdf
http://www.nextgenscience.org/sites/ngss/files/Appendix%20G%20-%20Crosscutting%20Concepts%20FINAL%20edited%204.10.13.pdf

Integrated STEM Lesson: Friction on the Road

Integrated STEM Education Lesson Plan

Topic: _Friction on the Road_ **Course**: _Introduction to Engineering_ **Grade Level**: _9-10_

Learning Objectives: By the end of the lesson, students will…

1. _Explain the concept of Friction as it relates to traction in an automotive system.__
2. _Analyze variables within the stated system and identify which variables significantly impact the efficiency of the system._
3. _Consider which variable(s) could be used in a design brief and identify which variable they will address in their design._
4. _Summarize the investigation and analysis in their notebook, it should include definitions of variables, descriptions of tests, data table of results, analysis, and a reflection._

Situating the Content:

1. What was previously taught? _Students should have a general understanding of how a car functions and how to analyze empirical data._
2. What will be taught next? _Following this lesson would be a design project to improve car efficiency._
3. Why this content is important to learn? _This content is important because students need to understand how scientific principles influence engineering design._
4. What is/are the I-STEM goal(s) [At minimum must include student learning]? _Interest and engagement, making connections_
5. What is the relationship between STEM connections (Concepts, Practices or Both)? _Both_
6. How does the addition of a supporting STEM field improve student:
    a. Understanding of the anchor discipline? _Students understand the concepts behind automotive design and the systems at work within the product._
    b. Understanding of the relationships between fields? _Students will experience how science principles influence design.___

Learning Standards:

1. Anchor domain: _ Standard #3: Understand the integrated relationship of technology with other academic fields, particularly language arts, math, science, and social studies._

2. Connector domain(s): _ Mathematics: PS.2: Reason abstractly and quantitatively; PS.3: Construct viable arguments and critique the reasoning of others._

3. Connector domain(s): _Integrated Chemistry – Physics: 9-10.RS.5 Analyze the structure of the relationships among concepts in a text, including relationships among key terms (e.g., force, friction, reaction force, energy)._

Assessment: _Student notebook entries and reflections. Grade based on rubric (below).__

Time	Teaching Method	Instructions & Learning Activity	Materials & Resources	Connections Content & Practices
5min		Introduction and Attendance		
5min	Computer-Assisted Lecture	Set Motivation • Video of cars and friction	Computer, video	
5min	Discussion-Based Lecture	Variable Brainstorm • What do we think affects Friction? • What variables did we see in the videos? • How can we test these variables?	Computer, PowerPoint, Projector	Friction, Inquiry
20min	Student-Centered Inquiry	Friction Investigation Activity • What is friction? • How does friction work? • What variables affect friction? • Is friction on a flat surface different from a rolling wheel? • What does this tell us about the nature of friction? • Is friction different between stopping and starting? • How about during movement?	Hot wheels track, 3D printed sled, hot wheels cars, various sliding materials	Inquiry, Friction, Physical concepts regarding motion, simple machines
10min	Discussion-Based Lecture	Systems, Automotive design, Friction • How does friction influence automotive design? • Why is it important? • Aim to bring out ○ Material, Weight, Size (surface area)	Whiteboard	Design, constraints and criteria, problem definition
5min	Discussion-Based Lecture	Design Possibilities • What variable are you choosing? • How can you manipulate this variable?	Notebook	
5min	Review & Closure	Review What is friction? Why is it important? Preview How can we improve automotive functionality using what we know? What is due? Notebook entry		

	Incomplete (1)	*Minimum (2)*	*Complete (3)*
Definition of Friction	Definition is incomplete or non-existent.	Coherent sentences articulate basic definition.	Definition and explanation accurately communicate the principle of physics.
List of Variables	List is missing key variables or is missing explanations.	List includes key variables and basic explanations.	Exhaustive list includes accurate explanations.
Observations	Incoherent notes or missing information.	Notes document process and results.	Notes include data, charts and explanations.
Summary and Reflection	Incomplete sentences or missing information. No reflection.	Summary includes key ideas in complete sentences. Reflection communicates basic understanding of content	Summary is clear and concise while including key ideas. Reflection communicates true understanding and accurate concepts.